Centre for Fish and Fisheries Research

Murdoch UNIVERSITY

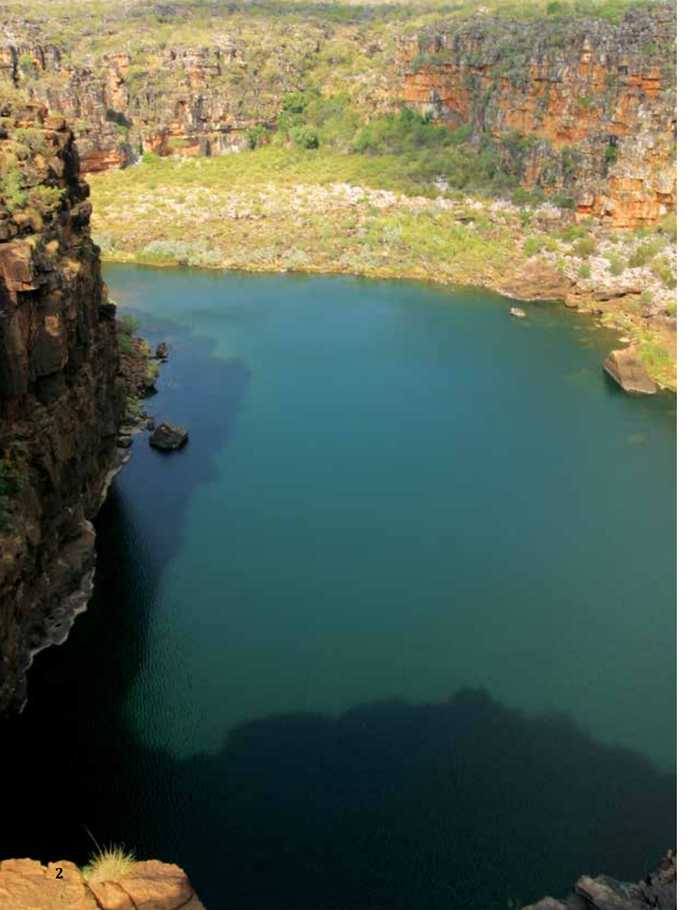
REPORT 2013 – 2014

CONTENTS

CENTRE FOR FISH & FISHERIES RESEARCH (CFFR)

The Centre for Fish & Fisheries Research at Murdoch University, Perth, Western Australia, was established in 2000 in recognition of a history of sustained and internationally recognised excellence in research and postgraduate training in fish and fisheries biology. Our main aim is to test traditional paradigms regarding fishes and their ecosystems to facilitate their sustainability. Our studies have focussed on the faunas and ecosystems of Western Australia, which have highlighted their uniqueness globally and refined our understanding of key aspects of fish biology and ecosystem function.

The quality of research and postgraduate training is reflected in members of the Centre having published over 600 papers in leading international journals, the receipt of substantial funding from State, National and International sources, and the graduation of almost 100 MPhil and PhD students.



From the Director

With the formation of the 'super' School of Veterinary & Life Sciences in 2013, which accounts for almost 60% of the University's research staff, the Centre for Fish & Fisheries Research has recently undertaken some restructuring. Long-serving Centre Director Professor Neil Loneragan is now the Node Leader of Wildlife Biology and Conservation within the School, and Acting Director Dr Howard Gill sought retirement to spend more time to pursue his love of fishing. I would sincerely like to thank both Neil and Howard for their leadership within the Centre, and wish them well in their new roles or pursuits, and acknowledge that both still remain very committed members of the Centre.

The Centre for Fish & Fisheries Research has continued to maintain its extremely productive outputs, with an average of over 40 peer-reviewed journal publications per annum since 2003, including over 125 between 2013 and June 2015. Centre members are to be commended for having also produced almost 20 books and 30 book chapters since 2003, including 7 books and 12 book chapters since 2013. The Centre members currently include 10 Academic Staff, 10 Post-doctoral Research Fellows, 38 PhD, MPhil or MSc students and 24 Honours students since 2013. I would also like to acknowledge the contributions of our Adjunct Researchers and Distinguished Collaborator and Professional appointments, who provide us with a wealth of experience in our research goals, and in the expert supervision of graduate students.

As the current Acting Director, it is with great pleasure that I get to work with a professional group of researchers that have the interests of fish and their habitats at heart, for the better of Western Australia.

David Morgan
Acting Director

Centre Members

CENTRE BOARD
Shaun Collin
Greg Jenkins
David Hampson
Brett Molony
David Morrison
Ian Potter
Ben Reilly
Andrew Rowland
Ian Stagles

DIRECTOR (Acting)
David Morgan

DEPUTY DIRECTOR (Acting)
Fiona Valesini

ACADEMIC STAFF
Lynnath Beckley
Jennie Chaplin
Mike van Keulen
Halina Kobryn
Susan Gibson-Kueh
Neil Loneragan
Alan Lymbery
Susan Moore
Ian Potter
Malcolm Tull

POST-DOCTORAL RESEARCH FELLOWS
Stephen Beatty
Joseph Christensen
Peter Coulson
Adrian Gleiss
Adrian Hordyk
Frazer McGregor
Sarah Metcalf
James Tweedley
Joel Williams

RESEARCH STAFF
Mark Allen
James Keleher
Jeff Whitty

DISTINGUISHED COLLABORATORS
Richard Warwick
Michael Elliott
Michael Landry
Ken Pollock

ADJUNCT RESEARCHERS
Bob Clarke
Jeffrey Dambacher
Nic Dunlop
Brendan Ebner
David Fairclough
Howard Gill
Norm Hall
Alex Hesp
Steeg Hoeksema
Gavin Partridge
Margaret Platell
Ken Pollock
Jeremy Prince
Matt Taylor

PHD STUDENTS
Mark Allen
Simon Allen
Eloise Ashworth
Kirsten Ball
Stacey Blane
Andrew Broadley
Amanda Buckland
Natasha Coen
Alan Cottingham
Jason Crisp
Ben French
Sarah Fretzer
Michelle Gardner
Vanessa Jaiteh
Michael Klunzinger
Melanie Koinari
Le Ma
Jo Marie Acebes
Abby Mitchell
Mikayla Morine
Jon Murphy
Brad Norman
Marianne Nyegaard
Owen O'Shea
Karen Paton
Brian Poh
Rebecca Roberts
Sam Robinson
Tom Ryan
Alicia Sutton
Gayani Thiakarathna
Michael Travers
Lauren Veale
Daniel Yeoh

MPHIL STUDENTS
Erin Kelly
Jeff Whitty

MSC STUDENTS
Cole du Plessis
Chrostopher Johnson
Elana Sulin

HONOURS STUDENTS
Tom Bateman
Amber Bennett
Leah Botton
Ellen Boylen
Andrew Broadley
Pearce Buchanan
Jake Chandler
Harriet Davies
Cameron Desfosses
James Florisson
Keyley Hogan-West
Peter Howie
Shona Jennings
Amy Kirke
James Laolada
Elizabeth Lavall
Jacqui Morgan
Brenton Pember
Natasha Prokop
Gary Ogston
Delia Quek
Stephanie Venables
Max Wellington
Lisa West

Student completions (2013-2014)

Doctor of Philosophy

Acebes, Jo Marie (2014). Historical catches of large marine vertebrates in the Bohol Sea: interactions of communities with their marine environment, socio-economic changes and conservation management implications in the Philippines. (Supervisors: Malcolm Tull & James Warren)

French, Ben (2013). The Diets of *Pagrus auratus* (Sparidae), and *Psuedocaranx georgianus* (Carangidae), the construction of a demersal food web and the biology of *Othos dentex* (Seranidae). (Supervisors: Margaret Platell & Ian Potter)

Fretzer, Sarah (2013). Analysing the effects of anthropogenic activities on two aquatic ecosystems in Western Australia and identifying sustainable policies for ecosystem-based management. (Supervisors: Neil Loneragan, Norm Hall & Jeff Dambacher)

Hordyk, Adrian (2014). The development and application of a length-based method to estimate the potential ration in data-poor fish stocks. (Supervisors: Neil Loneragan & Jeremy Prince)

Ingram, Michelle (2014). The effect of salinity on the resilience of riparian ecosystems. (Supervisor: Alan Lymbery)

Klunzinger, Michael (2013). Ecology and life history of the freshwater mussel *Westralunio carteri* (Iredale 1934) in the south-west of Western Australia. (Supervisors: Alan Lymbery, David Morgan & Stephen Beatty)

Koinari, Melanie (2014). Prevalence and molecular characterisations of gastrointestinal pathogens in sheep, goats and fish from Papua New Guinea. (Supervisors: Una Ryan & Alan Lymbery)

O'Shea, Owen (2013). The ecology and biology of stingrays (Dasyatidae) at Ningaloo Reef, Western Australia. (Supervisors: Mark Meekan, Mike van Keulen & Michelle Thums)

Roberts, Rebecca (2013). Economic strategies for coastal disaster risk reduction: A case study of Exmouth, Western Australia. (Supervisors: Lynnath Beckley & Malcolm Tull)

Veale, Lauren (2014). Inter-period comparisons of the ichthyofaunas of two nearby, modified estuaries and the biology of *Pelates octolineatus* (Terapontidae). (Supervisors: Ian Potter, Alex Hesp, Norm Hall & Peter Coulson)

Masters of Philosophy

Whitty, Jeff (2013). Utility of a multi-faceted approach in determining the habitat use of endangered euryhaline elasmobranchs in a remote region of northern Australia. (Supervisors: David Morgan & Colin Simpfendorfer)

Masters of Science

Johnson, Christopher (2013). Modern and historical data identify sperm whale (*Physeter macrocephalus*) habitat offshore of south-western Australia. (Supervisors: Lynnath Beckley & Halina Kobryn)

Sulin, Elana (2013). Comparisons of the size and age compositions and growth of King George Whiting (*Sillaginoides punctata*) in different regions in south-western Australia. (Supervisors: Jennie Chaplin & Alex Hesp)

Honours

Antipas, Kaija (2013). Diversity, growth rates and population size structure of a faviid dominated 'marginal' coral reef in Fremantle, Western Australia. (Supervisor: Mike van Keulen & Damian Thompson, CSIRO)

Arnold, Justine (2014) Nudibranchs of the Central Western Australian Coast. (Supervisor: Mike van Keulen)

Ball, Kirsten (2014). The ecophysiological effects of ocean acidification on the seagrass Posidonia australis and their calcifying epiphytes. A study using pulse amplitude modulated fluorometry. (Supervisors: Mike van Keulen & Navid Moheimani)

Bennett, Amber (2014). The influence of sediment compositions on the Western School Prawn *Metapenaeus dalli* in a temperate Australian estuary. (Supervisors: James Tweedley & Neil Loneragan)

Bennett, Lisa (2013). Studies of the diversity, abundance and feeding ecology of Opishtobranchia in Coral Bay, Western Australia. (Supervisor: Mike van Keulen)

Broadley, Andrew (2014). Assessing the potential for restocking the western school prawn *Metapenaeus dalli* in a temperate Australian estuary. (Supervisors: James Tweedley & Neil Loneragan)

Buchanan, Pearce (2013). The Chaetognatha of the Leeuwin Current System. (Supervisor: Lynnath Beckley)

de Silva, Thomas (2014). Effects of *Lyngbya majuscula* on the diversity and abundance of benthic macroinvertebrates during an *in situ* simulated bloom. (Supervisors: Mike van Keulen & Navid Moheimani)

King, Brandon (2014) Diversity and abundance of Nudibranchia under the Busselton Jetty with influence of water temperature. (Supervisor: Mike van Keulen)

Pember, Brenton (2014). Connectivity in the grass emperor, *Lethrinus laticaudis*. (Supervisor: Jennie Chaplin)

Quek, Delia (2013). Development of genetic markers for *Parartemia* (Crustacea: Anostraca) and preliminary results of genetic analysis. (Supervisor: Jennie Chaplin).

Venables, Stephanie (2013). Short-term behavioural responses of manta rays, *Manta alfredi*, to tourism interactions in Coral Bay, Western Australia. (Supervisors: Mike van Keulen, Lesley Brain & Frazer McGregor)

West, Lisa (2013). Diurnal variation in zooplankton communities and its relationship to whale shark (*Rhincodon typus*) movements at Ningaloo Marine Park, Western Australia. (Supervisors: David Morgan & Brad Norman)

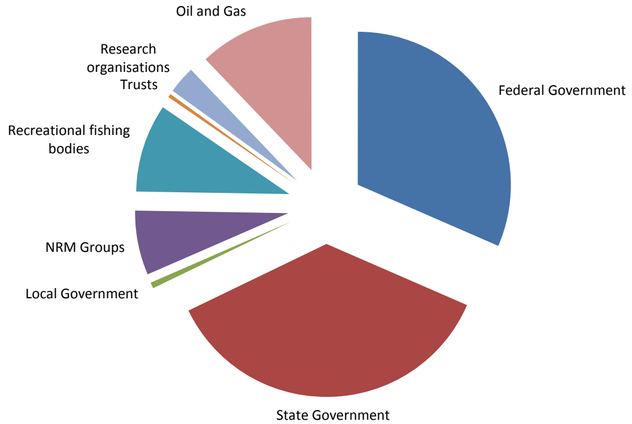
Yeoh, Daniel (2013). The gill net selectivity of four teleost species in south-western Australian estuaries. (Supervisors: Ian Potter & Norm Hall)

Funding providers and Collaborating Organisations

Between 2013 and 2014 the Centre for Fish & Fisheries Research staff worked on research projects that totalled $5,037,640.

- Austral Fisheries
- Australian Biological Resources Study (ABRS)
- Australian Centre for Applied Aquaculture (ACAAR)
- Australian Centre for International Agricultural Research (ACIAR)
- Australian Institute of Marine Science (AIMS)
- Australian Research Council (ARC)
- Australian Society for Fish Biology (ASFB)
- Cape to Cape Catchments Group
- Caring for Our Country
- Chevron Australia Pty Ltd
- City of Cockburn
- City of Swan
- City of Wanneroo
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Conservation Council of Western Australia
- Department of the Environment, Water, Heritage and the Arts (DEHWA)
- Department of Fisheries, Government of Western Australia
- Department of Parks and Wildlife, Government of Western Australia
- Department of Water, Government of Western Australia
- Fisheries Research and Development Corporation
- Geocatch
- Holsworth Wildlife Research Endowment
- Livering Pastroal Co.
- Rangelands NRM Western Australia
- Recfishwest
- Sea World Research and Rescue Foundation Inc.
- South East Regional Centre for Urban Landcare (SERCUL)
- South-West Catchments Council
- State Natural Resources Management (NRM) Office
- Swan River Trust
- The Crawford Fund
- TG Kailis Marine Conservation Fund
- University of Queensland
- University of Tasmania
- University of Western Australia
- Water Corporation
- Western Australian Fish Foundation (WAFF)
- Western Australian Marine Science Institution (WAMSI)

We would like to acknowledge and sincerely thank our funding bodies and our research collaborators for supporting the activities of the Centre in 2013 and 2014, and we aim to continue to conduct high quality, collaborative research and consultancies into the future.



MARINE MANAGEMENT RESEARCH GROUP

Teaching

Murdoch University offers a Bachelor of Science with a range of majors including Marine Science, Biological Science, Environmental Science, Environmental Management and Conservation & Wildlife. In addition, minors such as Fisheries Science, Marine Biology and Applied Statistics are offered. Students completing these courses find employment as fisheries biologists, marine ecologists, limnologists, conservation scientists and environmental consultants. Details about these courses can be found at www.murdoch.edu.au/Courses/Undergraduate-courses/. In addition, a range of graduate certificates, diplomas and course-work MSc options are available with details at: www.murdoch.edu.au/Courses/Postgraduate-courses/

Post-graduate Research

Murdoch University and the Centre for Fish & Fisheries Research offer an array of opportunities to complete Honours, Masters or PhDs. We currently have numerous post-graduate students studying various aspects of marine, estuarine or freshwater ecosystems.

Marine Management Research Group

Established in 2002, the Marine Management Research Group conducts a range of research projects in the Indian Ocean that generally provide the science that underpins management decisions. Over the past two years work has focussed on assessing human use of the remote Kimberley coast, examining the pelagic larval phase of the rock lobster phyllosoma larvae, krill and chaetognaths of the Leeuwin Current, habitat mapping and conservation planning at Ningaloo Reef and planning for the second International Indian Ocean Expedition.

Human use of the Kimberley coast

During 2013 and 2014, as part of the WAMSI Kimberley Marine Research Programme, much effort was put into conducting monthly aerial surveys along the remote Kimberley coast in order to map spatial and temporal patterns of human use in this region. Prof. Lynnath Beckley, Dr Claire Smallwood and Dr Emily Fisher completed >45 low altitude survey flights around the Dampier Peninsula between Broome and Derby, along Roebuck Bay and Eighty Mile Beach, and also in Camden Sound and the eastern Kimberley region. These surveys identified and geo-referenced both shore-based and boat-based activities, including recreational fishing, throughout much of the region. In addition, a comprehensive review of the potential impacts of this use was undertaken by Dr Joanna Pearce, an analysis of boat launching at Entrance Point boat ramp was conducted by Cameron Desfosses, and Prof. Beckley, Dr Fisher and Harriet Davies completed a desk-top study estimating cumulative visitation by expedition cruise vessels to this remote part of the coast. MSc student Cole du Plessis has started examining the temporal variability in this cruise vessel visitation.

Plankton research

Following on from an experimental study of the feeding preferences of rock lobster phyllosoma larvae which indicated that chaetognaths were a favoured prey item, Pearse Buchanan completed his Honours thesis during 2013 on the chaetognaths of the Leeuwin Current system. He examined plankton samples collected from 22°-34°S in shelf to oceanic waters and found clear zoogeographic patterns and several new distribution records for Australian waters. As part of the FRDC biological oceanography of rock lobster larvae project, the results of an extensive survey of prey fields in the SE Indian Ocean off Western Australia was published in the Journal of Plankton Research.

Alicia Sutton continued her PhD study on the zoogeography and ecology of krill in the SE Indian Ocean. She has completed her examination of krill diversity and abundance in plankton samples collected throughout the Leeuwin Current system, Ningaloo and Kimberley waters. These data fill a gap in her GIS collation of all published distribution records of krill in the Indian Ocean which she is using to link zoogeography with oceanography across the basin. In addition, she has been examining the trophodyamics of krill in the Perth Canyon using fatty acids and isotopes.

Max Wellington has started his Honours project investigating neustonic prey availability for seabirds across various meso-scale oceanographic features near the Abrolhos Islands. Shona Jennings has commenced her MSc project investigating oceanographic conditions in the Indo-Australian Basin between Java and NW Australia, the only place where the economically important, but severely depleted, global stock of Southern Bluefin Tuna spawn.

Benthic habitats and climate change resilience of Ningaloo Marine Park

Led by Dr Halina Kobryn, the project on high resolution mapping of the benthic habitats in Ningaloo Marine Park using hyperspectral imagery was completed in 2013 with the publication of a major paper in PlosOne. This work has already been used to support research on the distribution patterns of fishes at Ningaloo Reef. Honours student, Harriet Davies, has recently completed a study using these data and high resolution human use data for Ningaloo Marine Park to investigate climate change resilience features and adequacy of the current zoning in the park.

International Indian Ocean Expedition

Prof. Lynnath Beckley continued as the Australian representative on the international scientific committee of the SIBER programme which focuses on sustained biogeochemistry and ecosystem research in the Indian Ocean. In this role, she hosted an Indian Ocean National Forum at Murdoch in April 2014, attended various Indian Ocean reference group meetings in India, China and Mauritius and was invited to participate in a SCOR working group to write the science plan for the second International Indian Ocean Expedition (2016-2020). This has been recently ratified by the 140+ countries of the International Oceanographic Commission of UNESCO and the Expedition will be officially launched in India in November 2015. With Australia's new research vessel *Investigator* now commissioned, it is expected that it will be able to participate in Indian Ocean research voyages as part of the Expedition.

Other marine research

Whale Shark research

For over two decades Murdoch researchers, led by Brad Norman, have been monitoring the Whale Sharks of Ningaloo Marine Park. This long-term research has led to over 1000 individual Whale Sharks being indentified, and recent research is examining their movement patterns using acoustic telemetry, satellite tracking and daily diaries. Honours student Lisa West recently completed her theiss on the feeding ecology of this iconic species.

Foxfish otolith chronologies

Ellen Boylen has recently completed her Honours Project investigating the effects of selected environmental parameters on the otolith growth of the long-lived labrid, the Foxfish (*Bodianus frenchii*). Her supervisors were Peter Coulson, Adrian Hordyk, Ian Potter and Norm Hall.

Otoliths already collected by Steve Cossington during his Honours Degree between 2004 and 2006 were utilised in Ellen's research. The widths of successive growth increments, measured on sectioned otoliths, were detrended to remove any age related growth declines but preserve any climate signals, in order to construct the mean increment chronologies (MIC) for the *B. frenchii* populations at Rottnest Island on the south-west coast (Indian Ocean), and Esperance on the south coast (Southern Ocean). Aged individuals spanned 60 years, between 1953 and 2004. The MIC for the Esperance population was most strongly correlated with the Fremantle sea level, a measure of the strength of the Leeuwin Current, suggesting that warmer waters brought to the south coast by a strong Leeuwin Current positively influence otolith growth. In contrast, the MIC for the Rottnest population, was closely correlated with summer sea surface temperature.

Foxfish *Bodianus frenchii* (Photo: Ellen Boylan)

Sectioned otolith of a 51 year old Foxfish and a region at higher magnification showing indvidual increments and their corresponding years.

Genetic connectivity

Connectivity refers to the exchange of individuals between the assemblages of a species in different locations. An understanding of connectivity is fundamental to being able to assess and manage fisheries. Genetic assessments of the connectivity of a range of iconic species, including Black Bream (*Acanthopagrus butcheri*), Western Australian Salmon (*Arripis truttaceus*) and Blue Swimmer Crabs (*Portunus armatus*), have been completed in the past. Work in this area is continuing with Michelle Gardner's PhD research on Baldchin Groper (*Choerodon rubescens*) and Australasian Snapper (*Chrysophrys auratus*). This work was funded by the Western Australian Marine Science Institution. In 2014, Honours student Brenton Pember also completed a preliminary analysis of genetic connectivity in the Grass Emperor, *Lethrinus laticaudis*. These projects are being conducted in collaboration with the Department of Fisheries, Western Australia.

Further reading:

Moore, G.I. & Chaplin, J.A. (2013) Population genetic structures of three congeneric species of coastal pelagic fishes (*Arripis:* Arripidae*)* with extensive larval, post-settlement and adult movements. *Environmental Biology of Fishes* 96: 1087-1099

Genetic implications of restocking

Restocking is an increasingly important tool for the management of marine fish and crustacean populations. It involves growing large numbers of individuals of a particular species in a hatchery and then releasing them into the wild to supplement depleted stocks. An understanding of the extent and nature of the genetic implications of restocking is essential for the development of responsible restocking practices and such a study has recently been completed on restocking of Black Bream (*Acanthopagrus butcheri*) in the Blackwood River Estuary. Attention has now been turned to an investigation of the genetic implications of restocking the Western School Prawn (*Metapenaeus dalli*) in the Swan River Estuary, which is being done by Brian Poh as a part of his PhD research. Another project is investigating the implications of culturing Australasian Snapper (*Chrysophrys auratus*) from wild caught eggs. This is being undertaken by Honours student Natasha Prokop. These projects are being conducted in conjunction with Challenger Institute of Technology, Fremantle.

Harlequin Fish

One component of Ben French's PhD, which was completed in 2013 under the supervision of Ian Potter, Alex Hesp, Peter Coulson and Norm Hall was to determine the biological characteristics of the Harlequin Fish (*Othos dentex*), a highly sought after species by recreational and commercial fishers on the south coast of Western Australia. A unique finding from Ben's work was that, through the use of length and age compositions of females and males and histological analysis of the ovaries and testes, Harlequin Fish is a gonochorist, a sexual pattern only previously recorded definitively for one other anthiine serranid, i.e. Breaksea Cod (*Epinephelides armatus*), which also occurs in south-western Australia. Underwater observations of this species and evidence from low gonado-somatic indices for males, indicate that this species is a pair spawner. As their name suggests, Harlequin Fish are a brightly coloured species. Quantitative examination of the large spots on the lower half of the body of Harlequin Fish demonstrated that while these spots are similarly yellow in juveniles and adult females, they become blue in males at maturity and this intensifies during the spawning period, when they presumably play an important role in agonistic interactions among males and courtship with females.

The oldest fish in Western Australia: Bight Redfish

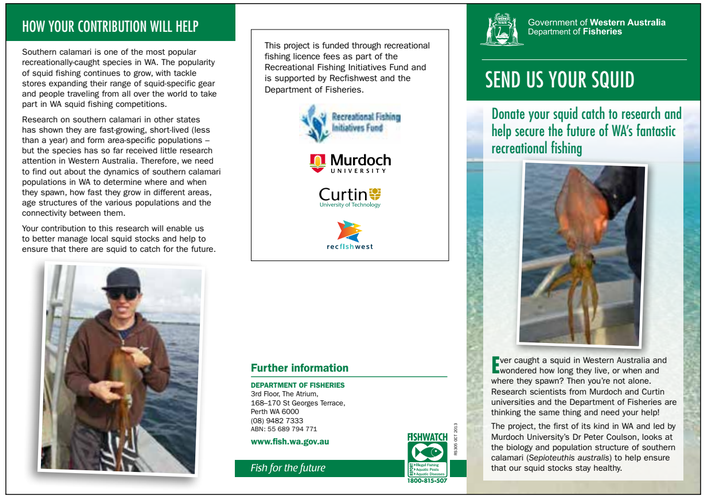
Bight Redfish is an important recreational and commercial fish species in southern Western Australia, however, little is known about its biology. Over the past four years, ~12,000 samples have been collected from the recreational and commercial fishing sectors in waters between Cape Naturaliste and the WA/SA border by researchers at Murdoch University (Peter Coulson and Ian Potter)and the Department of Fisheries (Jeff Norriss, David Fairclough, Tim Leary and Gary Jackson). These samples are being used to determine the age and growth, as well as the timing and duration of spawning of this species and, importantly, the length and age at maturation. Preliminary results for this State NRM funded project suggest that there is a decline in reproduction from west to east, which coincides with an increase in the length and age at maturity. Another important finding is that, like many other species in waters off the south coast, Bight Redfish is extremely long-lived, attaining a maximum age of 84 years, which makes it the oldest fish aged in Western Australian waters.

Bight Redfish *Centroberyx gerrardi* (Photo: Paul Lewis)

Southern Calamari

Jake Chandler is currently investigating the reproductive biology of Southern Calamari (*Sepioteuthis australis*) in south-western Australia for his Honours Degree under the supervision of Peter Coulson and Steve Leporati. This project is the first of its kind to employ recreational fishers to donate samples of a cephalopod in the "*Send us your squid*" program. Jake's Honours project is part of a larger Recreational Fishing Initiatives Fund project led by Peter Coulson, which aims to shed light on the biological characteristics of this recreationally and commercially important species.

The daily growth rings present in the statoliths, prepared by sanding and polishing both sides to give a thin transverse section, are being used to age individuals in order to determine growth and longevity. Preliminary results from over 3,300 samples collected by recreational and commercial fishers and by researchers from Albany on the south coast, Geographe Bay and Cockburn Sound, indicate that the growth and maximum size of Southern Calamari increases with increasing latitude (i.e. increasing gradient from warm to cooler waters). If you'd like to get involved, email Peter at p.coulson@murdoch.edu.au.



Comparisons of the diet of five species of flathead

This study has determined the extents and basis for variations in the composition of the prey ingested by the abundant species of a family highly adapted for ambush predation, i.e. Platycephalidae, in a region (south-western Australia) where that family is found in different habitats and environments. Dietary data were thus collected for *Leviprora inops* and *Platycephalus laevigatus* from seagrass in marine embayments and for *Platycephalus westraliae* from over sand in an estuary. These were then collated with those recorded previously for *Platycephalus speculator* from over sand and in seagrass in an estuary and for *Platycephalus longispinis* from over sand in coastal marine waters. While crustaceans and teleosts together dominated the diet of all five species, their percentage volumetric dietary contributions varied greatly, with those of crustaceans ranging from 7% for *L. inops* to 65% for *P. speculator* and those of teleosts ranging from 29% for *P. longispinis* to 91% for *L. inops*.

The investigators of this project include Peter Coulson, Margaret Platell, Bob Clarke and Ian Potter and funding was provided through FRDC.

The development and application of a length-based method to estimate the spawning potential ratio in data-poor fish stocks

Knowledge of the basic biological parameters of fish stocks, such as the natural mortality rate (M), the growth parameters (L_∞ and k) and the length at maturity (L_m), is important for many stock assessment methodologies. The ratios of these parameters (M/k and L_m/L_∞) have been found to be consistent between individual stocks of the same species. This research, which formed part of Adrian Hordyk's PhD studies, and was supervised by Neil Loneragan and Jeremy Prince, demonstrated the link between the variation in the ratios and the life-history strategy of a species.

Adrian conducted a meta-analysis of over 120 marine species, and examined the variation and patterns in the life-history ratios, and the relationships between size and spawning potential. The results of this study suggest that there is potential to establish a theoretical framework for 'borrowing' knowledge from well-studied species to apply to unstudied species.

Adrian developed analytical models to examine the relationship between these ratios and length structure, growth pattern, spawning-per-recruit, and the spawning potential ratio (SPR). He then extended these models to include more realistic assumptions about maturity and selectivity, to develop a model that estimates SPR from basic biological knowledge and length data; the length-based SPR model (LB-SPR).

The utility of the LB-SPR model, and its sensitivity to violations of the main assumptions, was examined using Monte Carlo simulations, and the results suggest that the model has potential to effectively estimate SPR for data-poor fisheries. However, the results also showed that care must be taken to evaluate the validity of the assumptions and the biological parameters of the model.

Finally, Adrian conducted a management strategy evaluation (MSE) to test a harvest control rule (HCR) that links the estimates of SPR from the LB-SPR model to an appropriate management decision. The results of the MSE indicate that the harvest control rule is capable of recovering an over-exploited stock within an acceptable time-frame and with acceptably low risk. However, the results also demonstrate that care must be taken when setting SPR target reference points.

This research provides a framework to estimate the relevant life history parameters for unstudied and data-poor stocks, and the LB-SPR model has the potential to be applied for the assessment of a wide range of otherwise unassessable stocks.

Historical perspectives of fisheries exploitation in the Indo-Pacific

Historical knowledge has an important role in addressing the problems facing marine capture fisheries today. The growing awareness of the value of historical perspectives underpinned the History of Marine Animal Populations (HMAP) project, a 10-year global research collaboration concerned with the long-term interaction of humans and the marine environment. HMAP Asia forms one of the 12 regional case-studies, and specifically addresses a lack of knowledge about the history of fishing and the historic impact of human activity on marine environments in Asia and Oceania. At a time when overfishing and declining fish stocks remain pressing problems for marine scientists and fisheries managers, the task of establishing baselines that expose the full extent of ecological change is as important as ever; understanding the scale and extent of historic change is a necessary first step towards achieving sustainability in marine capture fisheries. *Historical Perspectives of Fisheries Exploitation in the Indo-Pacific* represents an important step in what we hope will be ongoing international research on the marine environmental history of Asian and Pacific seas.

Further reading:

Christensen, J. & Tull, M. (eds.), *Historical Perspectives of Fisheries Exploitation in the Indo-Pacific,* MARE Publication Series 12, DOI 10.1007/978-94-017-8727-7_1, © Springer Science+Business Media Dordrecht 2014.

Citizen science monitoring of artificial reefs

Following the deployment of artificial reefs in nearshore coastal waters off Bunbury and Dunsborough, Honours students James Florisson and Tom Bateman have been using recreational fishers to collect underwater video footage of the different species of fish utilising these new potential habitats. The recreational fishers provide monthly videos recorded on their local artificial reef and nearby natural reefs, from which we quantify the composition of the fish fauna. The aim of this study, which is funded through the Recreational Fishing Initiatives Fund, is to determine whether citizen science can be used as a cost-effective tool for monitoring the fish communities of artificial reefs.

Coral Bay Research Station

Our research station in Coral Bay has been operational since 2004. The building, which was donated by the Brogan family, includes laboratory and office facilities and accomodation for up to 8 persons.

There are three boats and a 4WD vehicle available for researchers to use, and a recently donated glass-bottomed boat is currently being converted into a floating laboratory. Dive equipment and microscopes are also available for use by researchers.

For more information on the Coral Bay Research Station, please contact the Director, Mike van Keulen (M.Keulen@murdoch.edu.au).

Project Manta WA

We are delighted that Austral Fisheries and the TG Kailis Marine Conservation Fund have teamed up with Murdoch University researchers and the University of Queensland, Earthwatch and Ningaloo Marine Interactions to begin the most comprehensive study of Manta Rays to date. The Coral Bay Research Station is ideally located to be the base for this new program, as the locality of the largest known population of Manta Rays on the west coast of Australia occurs in Coral Bay.

Further reading:

O'Shea, Owen (2013). The ecology and biology of stingrays (Dasyatidae) at Ningaloo Reef, Western Australia. PhD thesis, Murdoch University. (Supervisors: Mark Meekan, Mike van Keulen & Michelle Thums)

Venables, Stephanie (2013). Short-term behavioural responses of manta rays, *Manta alfredi*, to tourism interactions in Coral Bay, Western Australia. Honours thesis, Murdoch University. (Supervisors: Mike van Keulen, Lesley Brain & Frazer McGregor)

Stumpy the Whale Shark:

the unmistakable giant of Ningaloo

Ningaloo Reef is the longest fringing reef in Australia and one of the longest in the world. It and the surrounding region was declared World Heritage in 2009, largely because of the annual appearance of the world's largest fish, the Whale Shark (*Rhincodon typus*).

The most famous of these individuals is 'Stumpy' – so called because of his noticeable oddly-shaped tail.

Stumpy was originally recorded at Ningaloo in 1994 and was the first Whale Shark listed in the global Whale Shark photo-identification database – his codename is A-001.

Since then, Stumpy has been recorded at Ningaloo almost every year – with 67 sighting encounters recorded in the database between 1995-2015.

Murdoch University has pioneered research on this threatened species at Ningaloo, with over two decades of continuous monitoring.

The Whale Shark was named Western Australia's official marine emblem in 2013, and the work on Whale Sharks at Ningaloo is globally recognised as the most comprehensive monitoring program worldwide.

Stumpy's spot patterning reproduced at Sculture by the Sea (phtograph: Olivia Samec).

ESTUARINE RESEARCH UNIT

Overview

The Estuarine Research Unit holds an unrivalled fish and invertebrate database for the estuaries of south-western Australia, which has been built progressively since the late 1970s. This data set, containing faunal community records and detailed biological information for most recreationally or commercially targeted species, provides an extremely rare and invaluable basis for understanding long-term ecological 'change' in these estuarine systems.

Expertise within the group cover faunal ***community ecology*** (assemblage structure and response to environmental drivers, ecosystem function along resource sharing pathways); ***biology*** (growth, reproduction, age, mortality, diet); ***genetics; restocking; fish behaviour and movement patterns; habitat classification and faunal prediction tools*** and; ***biotic indices of ecosystem health.*** The group has also more recently strengthened research linkages to better connect estuarine ecological health response and ecosystem service provision with key catchment drivers.

The Estuarine Research Unit works closely with State management, community and research agencies and has strong international research connections, including through several Adjunct and Distinguished Professor/Collaborator appointments. These international research linkages have facilitated many core comparisons that highlight the unique environmental and ecological features of the micro-tidal estuaries in south-western Australia compared to many of the large macrotidal estuaries of the northern hemisphere.

This section examines some of the work undertaken by the Estuarine Research Unit in 2013-15. For more information, contact Dr Fiona Valesini (f.valesini@murdoch.edu.au).

How healthy are our estuaries?

Monitoring estuarine ecological health using Fish Community Indices

Indicators based on biotic communities are used to monitor and report the ecological condition or health of estuarine ecosystems worldwide, distilling how well the underlying ecosystem structures, processes and functions are operating. However, Australia has been less quick to develop and adopt these core indicators.

With initial funding support from the Swan River Trust, Department of Water, Department of Fisheries and Murdoch University, researchers in the Estuarine Research Group were the first in Australia to develop one such tool, based on fish communities, in 2009/10. This Fish Community Index (FCI) and supporting fish monitoring program has now been used in each year since 2011 to assess and report the condition of the iconic Swan-Canning Estuary, through funding support from the Swan River Trust. This index is also currently being adapted to other estuaries in south-western Australia, including the Walpole-Nornalup.

The FCI combines information on a suite of 'metrics', each of which quantifies an aspect of the structure and/or function of estuarine fish communities and responds to a range of stressors affecting the ecosystem (Fig. 1). These metrics are measured from the fish monitoring data, then compared to historical 'reference conditions' that represent the best ecosystem condition observed over the last 30-40 years. Establishing these references has been made possible through the extensive fish community data sets collected by the CFFR in the Swan-Canning Estuary since the late 1970s. Metrics are scored based on their deviation from these benchmarks, then integrated into a final FCI score (0–100) and a corresponding 'report card' grade (A; very good – E; very poor) that reflects the overall condition of the estuary and its various zones (Fig. 2).

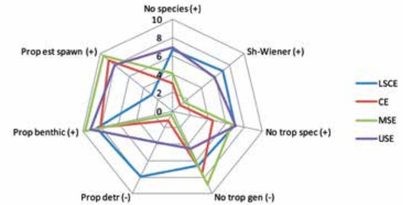


Fig. 1: Example of the metrics used to calculate the Fish Community Index (*No species*, number of species; *Sh-Wiener*, Shannon-Wiener diversity; *No trop spec*, number of trophic specialists; *No trop gen*, number of trophic generalists; *Prop detr*, proportion of detrivores; *Prop benthic*, proportion of benthic species; *Prop est spawn*, proportion of estuarine spawning species).

The FCI enables estuary managers to understand how the ecological condition of the estuary varies over time and space, and how it responds to factors such as algal blooms, periods of low oxygen and changes in river flows. The indices also provide a simple and visual method for communicating estuary health to the public, politicians and other stakeholders.

In the Swan-Canning Estuary, the FCI has shown that the health of the shallow nearshore waters has generally remained good to fair (grade B/C) in recent years, following an apparent improvement in condition between 2005/06 and 2008/09. Similarly, the offshore deeper waters of the estuary have generally been in a fair-good (C/B) condition since 2011. However, there are indications that these deeper waters are in poorer health than the adjacent nearshore areas, and that particular zones of the estuary (e.g. the Canning Estuary and upper Swan Estuary) most frequently decline in health (e.g. grade D) due to perturbations such as algal blooms and low dissolved oxygen levels (Fig. 2).

Fig. 2: Example of the FCI 'report card' grades in the offshore waters of each major zone of the Swan-Canning Estuary in summer and autumn 2015.

The CFFR continues to work closely with the Swan River Trust to understand the drivers of these indices and the ways in which particular stressors impact on the ecological health of the estuary. We are also working to predict how estuarine health might change in future years due to the effects of climate change, and particularly in response to the declining river flows that are predicted for south-western Australia.

Further reading:

Hallett, C.S. (2014). Quantile-based grading improves the effectiveness of a multimetric index as a tool for communicating estuarine condition. *Ecological Indicators* 39: 84-87.

Hallett, C.S. & Tweedley, J.R. (2014). *Assessment of the condition of the Swan Canning Estuary in 2014, based on the Fish Community Indices of estuarine condition.* Murdoch University, Perth, WA, 32 pp. (http://www.swanrivertrust.wa.gov.au/docs/technical-reports/assessment-of-the-condition-of-the-swan-canning-estuary-in-2014-based-on-the-fish-community-indices-of-estuarine-condition.pdf).

Other ecological indicators of estuarine health – evidence from the benthos

Small benthic (bottom-dwelling) invertebrates undertake core functions in estuarine systems, such as decomposing organic material and nutrient cycling, and they are a fundamental food source for many fish and bird species. They also provide excellent indicators of environmental change and, like fish, have been used worldwide to evaluate the ecological health of estuarine waters.

Several projects in the Estuarine Research Unit since 2013 have focussed on examining changes in these invertebrate communities to better understand the impacts of acute or chronic perturbations on estuarine health.

Drs James Tweedley and Chris Hallett led a project in the Swan-Canning Estuary (funded by the Swan River Trust) that revealed the dramatic impacts of a severe storm, which hit Perth in March 2010, on the invertebrate communities in the upper reaches of this system. Large and sudden inflows into the estuary caused the water column to become highly stratified, resulting in extensive and persistent deoxygenation of the bottom waters of the upper estuary. This event coincided with a CFFR study of the effects of oxygenation on the benthic invertebrate communities of the estuary, thus allowing the impacts of this major hypoxic event on these fauna to be examined.

The number and diversity of invertebrate species underwent a dramatic decline, and crustacean species (known to be among the most sensitive to environmental perturbations) effectively disappeared from all sites. The invertebrate community did not fully recover until after the end of the hypoxia, some four months later. These results emphasise that microtidal estuaries such as the Swan Canning, which have long residence times, are highly vulnerable to the effects of environmental perturbations.

Dr James Tweedley, together with Distinguished Collaborator Prof. Richard Warwick (Plymouth Marine Labs, UK) and Prof. Ian Potter, have also recently examined differences in a range of biotic metrics for the benthic macroinvertebrate communities in 16 estuaries and 34 coastal sites in the United Kingdom. Their study has again demonstrated the usefulness of these fauna as indicators of anthropogenic disturbance (toxic heavy metal loads in this case), particularly if changes in their taxonomic distinctness (a comprehensive biodiversity measure) are examined. Further work undertaken in conjunction with Prof. Warwick has demonstrated that a particular measure ('AMBI' - AZTI's Marine Biotic Index), widely used across the world and particularly in Europe for detecting the extent of ecological degradation in estuaries, did not work in south-western Australian systems due to their unique characteristics. Work is also currently underway on a large review of the unique ecology of microtidal estuaries around the world.

Current PhD student Samuel Robinson, who commenced his study in March 2014 and is supervised in a collaborative arrangement between Murdoch University (Drs Fiona Valesini and James Tweedley) and the University of Western Australia (Assoc. Prof. Matthew Hipsey), is also further advancing our understanding of how estuarine benthic invertebrate communities respond to longer-term change and how their nutrient cycling capacity is impacted by hypoxia.

The main objectives of Sam's study are to (1) examine the nature, extent and drivers of any changes in the benthic macroinvertebrate community in the upper Swan-Canning Estuary since the mid-1990s (supported by historical data collected by the CFFR); (2) determine how the nutrient flux capacity of key species is impacted by hypoxic and variable dissolved oxygen conditions; and (3) support development of a modelling framework to forecast the physico-chemical and ecological response of the estuary under different environmental (e.g. climate) scenarios.

The outcomes of Sam's work will not only be used to further our understanding of how the ecological health of the Swan-Canning Estuary is changing over time, but also to supplement a high resolution hydrological-biogeochemical model which is currently being developed for the entire Swan-Canning Estuary (led by Matthew Hipsey, UWA, and funded by the Swan River Trust with the support of the Department of Water). This model framework will represent a major advance in the ability to predict complex estuarine response to forcing environmental conditions or different management strategies, and has vast applications as a management and research tool, not only in the Swan-Canning but in other comparable microtidal estuaries worldwide.

Further reading:

Tweedley, J.R., Hallett, C.S. Warwick, R.M., Clarke, K.R. & Potter, I.C. (2015). The dramatic effect of an extreme weather event on the benthos of a microtidal estuary. *Marine and Freshwater Research.*

Tweedley, J.R, Warwick, R.M. & Potter, I.C. (2015). Can biotic indicators distinguish between natural and anthropogenic environmental stress in estuaries? *Journal of Sea Research* 102, 10–21.

Tweedley, J.R., Warwick, R.M., Clarke, K.R. & Potter, I.C. (2014). Family-level AMBI is valid for use in the north-eastern Atlantic but not for assessing the health of microtidal Australian estuaries. *Estuarine, Coastal and Shelf Science* 141: 85-96.

The Vasse-Wonnerup - understanding a unique wetland of international importance

The Vasse-Wonnerup system on the lower west coast of Australia is designated as a Wetland of International Importance under the Ramsar Convention, providing habitat for ~40,000 waterbirds representing approximately 90 species. It has a highly unusual morphology and hydrology, the latter of which has been majorly altered by land drainage networks and floodgates which prevent the intrusion of seawater. It has also exhibited increasing signs of ecosystem decline through eutrophication, algal blooms, anoxia, fish kills and foul odours, raising considerable community concern about its health status and its future.

Despite the above, relatively little was known until recently about key aspects of its environmental and ecological function. CFFR members have played a major role in helping to fill some of these knowledge gaps over the last few years, and are continuing to do so through a range of collaborative research projects. These are outlined briefly below.

Fish faunas of the Vasse-Wonnerup

Little was known of the fish fauna of this system until a comprehensive study, led by Drs James Tweedley and Steve Beatty, in 2012-15. To date, 38 species of fish, including two introduced freshwater species, have been found within the system. The distribution and abundance of most species is strongly linked to changes in salinity, which can range from 1 to 130 ppt within a few months. The results have also highlighted regions of the systems that are crucial for maintaining sustainable fish populations following periods of poor water quality and fish kills. This research, was funded by Caring for Our Country and GeoCatch, and is guiding improved management plans for this system.

Further reading:

Tweedley, J.R., Keleher, J., Cottingham, A., Beatty, S.J. & Lymbery, A. (2014). The fish fauna of the Vasse-Wonnerup and the impact of a substantial fish kill event. Report for Geocatch. Murdoch University, Perth, Western Australia. 113 pp.

Fish tracking and citizen science helping to solve fish kills in the Vasse-Wonnerup Estuary

Fish kills have occurred regularly in the lower Vasse-Wonnerup Estuary in recent years. It is the larger-bodied fish species, such as Black Bream and Sea Mullet, that are most susceptible to such mortality events in this system. However, very little is known about how these species move within the estuary, and particularly around the flood gates.

A collaborative project funded by a State NRM Community Grant in 2015 is aimed at determining the movements of Black Bream and Sea Mullet in the Vasse-Wonnerup Estuary using acoustic tagging techniques. The study is underpinned by a strong citizen science and community engagement approach with Busselton Senior High School students, along with the broader recreational fishing community during a weekend of tagging fish. The WA Department of Fisheries have also contributed to this project.

Preliminary results have revealed that Black Bream are highly mobile and can move on average at least 14 km/day, primarily throughout the Wonnerup Inlet and Deadwater regions. There is very little passage of fish through the floodgates.

This study provides crucial data for helping refine operation of the floodgates and determining minimum gate widths required for fish passage. This is being achieved by incorporating fish tracking data with hydrological information from a gate operation trial (supported by Water Corporation and Department of Water).

This study has been highly successful in bringing together researchers, managers and the community to gather supporting information for better managing this unusual and complex system.

Integrating human use values and estuary-catchment science

Estuarine management needs to be underpinned by a sound scientific understanding of ecosystem structure and processes, but also needs to align with social and political realities and community expectations.

In an innovative and collaborative research program, led by Drs Fiona Valesini and Jane Chambers and funded by the South West Catchments Council (SWCC) through a grant from the Australian Government, four PhD/Masters projects spanning the ecological and social sciences will work together to better support the management of the Vasse-Wonnerup system.

This research program, which will operate from 2015-18, brings together expertise from four universities (Murdoch, Edith-Cowan, Curtin and Southern Cross) and various management and community-based agencies, including not only SWCC but also the Department of Parks and Wildlife, Geocatch and the Conservation Council of WA.

The four projects and their various contributors are as follows.

1. *Identifying the nutrient and carbon sources and sinks within the Vasse Wonnerup wetlands.* Led by Assoc. Prof. Glenn Hyndes (Edith-Cowan), together with Dr Jane Chambers (Murdoch) and Prof. Bradley Eyre and Dr Joanne Oakes (Southern Cross).

2. *Who eats what in the Vasse-Wonnerup Estuary? Constructing a quantitative and predictive food web for this wetland system.* Led by Dr Fiona Valesini, together with Dr James Tweedley, Dr Steve Beatty (Murdoch) and Assoc. Prof. Glenn Hyndes (Edith-Cowan), with additional expertise provided by Prof. Mike Bunce (Curtin), Jane Chambers (Murdoch), Jim Lane (Dept Parks and Wildlife) and Nic Dunlop (Conservation Council WA).

3. *Understanding community values, perceptions and knowledge: assisting adaptive management of the Vasse-Wonnerup wetlands* (PhD student Shivani Purushothaman).Led by Prof. Sue Moore, Dr Kate Rodgers (Murdoch) and Maria Ryan (Edith-Cowan).

4. *Adaptive management and the environmental policies of the Vasse-Wonnerup wetlands* (Masters student Kristen Holgate).Led by Prof. Sue Moore, Dr Kate Rodgers (Murdoch) and Maria Ryan (Edith-Cowan).

The Peel-Harvey Estuary – changes in its fish fauna since the 1980s

Inter-decadal changes in the fish fauna

Because the Peel-Harvey Estuary became highly eutrophic in the 1970s and 1980s, reflected in massive growths of macroalgae and prolific seasonal blooms of the cyanobacterium *Nodularia spumigena*, a large artificial channel was opened in 1994 to increase the flushing of nutrients from this large estuarine system.

Previous studies in 1980/81 and 1996/97 demonstrated that the resultant changes to the tidal and salinity regimes and amount of macroalgae were accompanied by a decline in the abundance of fishes, but an increase in their species richness and a change in species composition. Data on the ichthyofaunas at sites throughout the Peel-Harvey Estuary in 2008/10, when macroalgal and macrophytes growths had increased since the channel opening, were collected and compared with those in the two earlier periods using contemporary statistical methods.

Ichthyofaunal composition changed with period, due, in particular, to the relative abundances of the 'weed-associated' species *Pelates octolineatus* and *Ostorhinchus rueppellii* decreasing between the 1980s and 1990s and then increasing. Species composition changes with season in the later two periods, but not in the earlier period when tidal water movements were far less. Furthermore, composition was related far more to region in the earliest and latest periods, when weed-associated species were more abundant and especially so in certain regions.

Biology of the Western Striped Grunter (*Pelates octolineatus*)

As part of her PhD, Lauren Veale studied the biology of the Western Striped Grunter, otherwise known as the Eight-lined Trumpeter, in south-western Australia. This species is a classic marine-estuarine opportunist, using both nearshore coastal waters and estuaries as a nursery area. Lauren showed that many individuals of this species live in dense seagrass in protected coastal waters for the first year of life and then move into areas of sparser seagrass, where they spawn at the end of the second year and subsequent years of life. However, large numbers of young juveniles of the Western Striped Grunter move into estuaries and are particularly abundant in systems when they contain extensive growths of macroalgae and/or seagrasses. The juveniles grow rapidly in estuaries, such as the Peel-Harvey, and move out into the marine environment in winter, when they are about 18 months old, and where they spawn in the following summer. The growth of this grunter is greater in estuaries than coastal marine waters, presumably reflecting the greater productivity in the former systems.

Western Striped Grunter *Pelates octolineatus*
(Photo: Chris Dowling)

Bringing back prawning in the Swan River

At the end of a long, hot summer Perth day, it was typical to see lanterns and fires around the Swan and Canning rivers, where generations of West Aussies would go to catch and cook a bucket of prawns. Western School Prawn (*Metapenaeus dalli*) numbers declined steadily throught the 1990s, to the point where only a handful of ardent recreational prawners were left by 2000.

Community concern about this issue led to a collaboration between the Australian Centre for Applied Aquaculture Research (ACAAR), the Swan River Trust (SRT) and the CFFR (funded by the Recreational Fishing Initiatives Fund, Fisheries Research Development Corporation and SRT) to launch a restocking program for this species. This program, which began in 2013 and continues through 2015, has three main aims; (1) produce juvenile prawns via aquaculture for restocking into the estuary (led by Greg Jenkins, ACAAR); (2) undertake biological and ecological studies of this prawn species to maximise restocking success (led by James Tweedley and Neil Loneragan, CFFR); and (3) engage and educate the community through developing a dedicated citizen science program (led by Kerry Trayler, SRT).

Aquaculture

Aquaculturists at ACAAR achieved a world first by culturing eggs from gravid (pregnant) females collected from the estuary and growing them through the naupliar, protozoeal, mysis and initial post-larval stages to produce juvenile prawns for release. The far smaller size of Western School Prawns compared to other cultured prawns initially proved challenging, with only ~1,000 prawns being bred and released in summer 2013. The development of novel aquaculture methods by the ACAAR team to overcome these difficulties has since led to the release of ~630,000 prawns in 2014 and ~2 million in 2015.

Science

Successful growth of many species in aquaculture is typically supported by extensive data on their biology and ecology. However, this was not the case with *M. dalli*, where little such information existed. To fill this knowledge gap, research effort in the current project was focused in three areas, namely larval growth and development, biology and ecology, and maximising restocking success. The larval work is being undertaken by PhD student Jason Crisp. Jason's research has firstly described larval development and has since determined the optimum temperature and salinity for survival and growth. He is now working on determining the most effective microalgal feeds and a protocol for identifying broodstock in peak reproductive condition.

Ecological studies of the prawns (i.e. their spatial and temporal distribution in the estuary and potential environmental drivers) are being led by PhD student Brian Poh and Dr James Tweedley, who have undertaken an extensive sampling program in the shallow and deeper waters of the system in every month for two and a half years. Brian is currently correlating patterns in prawn abundance with a range of environmental variables. Brian is also investigating the genetic implications of restocking the Western School Prawn in the Swan River Estuary. Honours student Amber Bennett (who submitted her thesis in 2014) also examined the sediment preference of this prawn species through complementary field sampling and laboratory experiments.

Andrew Broadley, who also completed his Honours project in 2014, determined a range of biological characteristics of *M. dalli* including timing of reproduction, size/weight at reproduction and growth and mortality rates. Andrew is now undertaking a PhD in the CFFR, and is using the above characteristics to determine prawn biomass in the system and develop a bio-economic model to determine the costs and benefits of restocking.

Work is also being undertaken by Brian and current student Kyle Hodgson to identify the fish species that predate on juvenile prawns.

Community engagement

A citizen science program for recreational prawners, 'Prawn Watch', was established by SRT in 2013 with the aim of (1) re-engaging people with prawning in the Swan-Canning Estuary; (2) educating the community on the prawn species in the system and sustainable fishing practices; (3) collecting data on the spatial and temporal abundances of prawn species targeted by recreational fishers; and (4) aiding collection of prawn broodstock for the aquaculture component of the project.

Multiple community training events have been held across the metropolitan area. Waterproof logbooks and a Smartphone application were also developed and provided to all participants to aid collection of robust data by recreational prawners.

More details about Prawn Watch can be found at: http://riverguardians.com/projects/prawn-watch.

For information about prawning go to: http://www.fish.wa.gov.au/Species/Prawn/Pages/Prawn-Recreational-Fishing.aspx

A quarter of a century of Black Bream research

The Black Bream (*Acanthopagrus butcheri*) is the most important recreational fish species in the estuaries of southern Australia and also contributes to the commercial fishery in some of these systems. This species is thus of enormous social and economic value. During the last 25 years, Ian Potter and numerous excellent research students and post-doctoral fellows, including Gavin Sarre, Margaret Platell and Ben Chuwen, have studied various aspects of the biology of this iconic species in several key estuaries on the lower west and south coasts of Western Australia.

Biological characteristics of Black Bream

Recently, the Recreational Fishing Initiatives Fund (RFIF) funded Ian Potter to collect data on Black Bream in nine key estuaries across south-western Australia, which could then be incorporated into the massive dataset collected by the CFFR since the early to mid-1990s for this species. The aim of this study is to compare the biological characteristics of Black Bream in different estuarine environments and over time to produce a composite picture of these characteristics. The results will enable recreational and commercial fishers to understand fully how the biological characteristics of this highly adaptable species vary among estuaries and alter in response to environmental changes. They will also provide fisheries and environmental managers with key data for conserving this important species.

Joel Williams (Post-doctoral research fellow), whose PhD was on the biology of Black Bream in the Gippsland Lakes in Victoria, and PhD students Alan Cottingham and Eloise Ashworth are playing a crucial role in this RFIF project. Recreational and commercial fishers are being very helpful with tagging studies and in providing frames of Black Bream. Joel is responsible for running the complex field sampling program and tagging studies and is using his expertise to explore, through sampling larval Black Bream, some of the factors that influence recruitment, such as the volume of freshwater flow.

Alan Cottingham's study has demonstrated that, in the Swan River Estuary between the early 1990s and mid-2000s, the growth, body condition and length at maturity of Black Bream has declined and age at maturity has increased (Fig. 1). These changes parallel declines in rainfall and thus reduced flushing of the estuary, thereby leading to a decline in oxygen concentrations in the deeper waters of the system. Fish densities in these deeper areas have declined while those in the nearshore shallow waters have increased, suggesting an onshore migration of this species to avoid the reduced environmental quality of the offshore waters. The greater densities of fish in the shallows accounts, at least in part, for the above changes in the biological characteristics of Black Bream. This study was funded by the Swan River Trust, Department of Fisheries, Department of Water and Murdoch University.

Eloise Ashworth's PhD involves developing a new model, derived from otolith measurements, to produce more reliable back-calculated estimates of the lengths of fish at different ages. This will allow determination of the extent to which fish growth is influenced by inter-annual variation in environmental factors, such as temperature. Her project employs data from previous CFFR studies on not only Black Bream, but also Mulloway, Foxfish, Breaksea Cod, Estuary Cod and Dhufish. The form of generalised growth model that best described the relationships between fish lengths and age at capture, and between otolith radius and age at capture, was determined for each species. The lengths and otolith radii, predicted by the somatic and otolith growth curves for fish of different ages, were then used to describe the relationship between expected fish length and expected otolith radius for fish of the same age. A back-calculation approach, which employed this relationship and thus allowed for the changes in somatic and otolith growth rates throughout the life of fish, was then developed and tested. The study is developing well and will highlight differences in the pattern of growth among species and the relationship of growth to environmental variables.

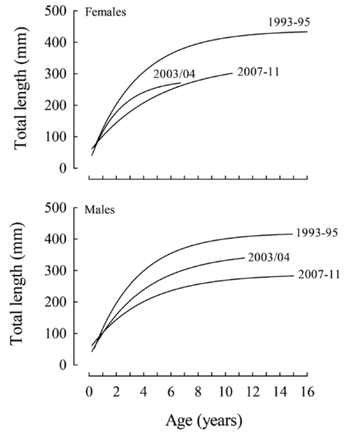


Fig. 1: Changes in the growth of female (top) and male (bottom) Black Bream in the Swan-Canning Estuary from the mid-1990's to late 2000s

Restocking the Blackwood River Estuary

A marked decline in the numbers of Black Bream in the Blackwood River Estuary led to a project, funded by the Fisheries Research and Development Corporation, Western Australian Fishing Foundation and Recfishwest, which was aimed at determining whether restocking was an effective way of replenishing depleted populations of this species. Greg Jenkins and his colleagues at the Australian

Centre for Applied Aquaculture Research, thus cultured juvenile Black Bream and stained their otoliths (ear bones) with Alizarin complexone (Fig. 2), after which they were released into the Blackwood River Estuary in 2002 and 2003. As the pink stain in the middle of the otoliths still remains visible, the progress of these restocked Black Bream has been able to be followed for 13 years. The results show that restocked fish perform nearly as well as wild stock and can make a major contribution to the recreational and commercial fisheries and also contribute to future generations. A study of the genetic implications of this restocking program was also recently completed.

Fig. 2: Unstained and stained otoliths from juvenile Black Bream (top) and an otolith from a 12 year old fish showing the pink stain in the central region (bottom).

Joel's preliminary results for the Blackwood River Estuary indicate that, after hatching, the larvae of Black Bream move into deeper waters. The low oxygen concentrations in these areas would be likely to lead to the substantial mortality of larvae, and thus account for the poor recruitment of this species.

Further reading:

Gardner, M.J., Cottingham, A., Hesp, S.A., Chaplin, J.A., Jenkins, G.I,. Phillips, N.M. & Potter, I.C.P. (2013) Comparisons of the biological and genetic characteristics of restocked and wild individuals of a sparid (*Acanthopagrus butcheri)* in an estuary. *Reviews in Fisheries Science* 21: 441-445.

Fish tracking and ecology in the Walpole and Nornalup Inlets Marine Park

The Estuarine Research Unit is re-visiting the Walpole-Nornalup Inlet system, one of the only permanently-open estuaries on the south coast of Western Australia and one of just three gazetted Marine Parks in estuaries State-wide, to re-examine its fish communities for the first time in over 20 years and track the movement patterns of key species targeted by recreational fishers.

In a collaborative project funded by the WA Department of Fisheries and Murdoch University, PhD student Daniel Yeoh will assess (1) spatial and temporal differences in the fish faunas throughout the estuary, including how they may have changed since the early 90s; (2) movement patterns of Black Bream, Southern Bluespotted Flathead, Pink Snapper and Tarwhine using acoustic telemetry; and (3) the ability to develop a fish-based index of estuarine health to track the ongoing ecological condition of this Marine Park.

Supported by additional funding from Recfishwest, Dan is also developing community engagement activities to promote greater understanding of sustainable fishing practices and estuarine health. The Walpole-Nornalup is a popular eco-tourism and recreational fishing destination, and this project has generated considerable interest and support among the fishing community.

Seasonal sampling of fish assemblages throughout the Walpole-Nornalup began in July 2014, and has so far yielded 43 species from 27 families. Preliminary data analyses indicate marked differences in fish species composition between regions of the estuary, seasons and between day and night.

An array of 17 acoustic receivers has also been deployed throughout the estuary to track individual fish tagged internally with acoustic transmitters. With the assistance of local recreational fishers, 23 Black Bream and 16 Southern Bluespotted Flathead have so far been tagged, and an additional 10 Pink Snapper and 10 Tarwhine are set to be tagged in mid-2015. Detailed movement data gathered will be used to compare how these four species use the system and each respond to various biological, environmental and anthropogenic drivers.

The tracking of three co-occurring sparids, i.e. Black Bream, Pink Snapper and Tarwhine, provides a unique opportunity to examine habitat overlap and potential resource competition among closely related species in an estuary.

This PhD project, which is set for completion in early 2017, is supervised by Drs Fiona Valesini, Joel Williams and Chris Hallett from the Estuarine Research Unit and Dr Dave Abdo from the WA Department of Fisheries.

Freshwater Fish Group
Fish Health Unit
Centre for Fish & Fisheries Research

FRESHWATER FISH GROUP

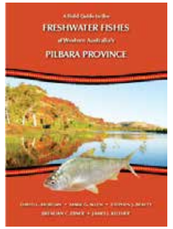
Overview

The Freshwater Fish Group maintains the most extensive database of fishes in inland waters in Western Australia, which has been achieved through the monitoring of most river systems in the State. Our work encompasses research on most fish species in WA inland waters and their habitats, including diadromous species and feral fish. Below we outline a few of our current projects. For more information visit www.freshwaterfishgroup.com

Research projects

Fishes of the Pilbara - field guide and documentary

During 2013 and 2014 the group was involved with ENVfusion Films in the making of a documentary of the fishes of the Pilbara. This accompanied a field guide depicting each of the region's unique fishes, as well as the feral species, plus other fishes of estuarine or marine origin that frequent fresh waters. This was a joint initiative of the Rangelands NRM Coordinating Group and the Western Australian Government's State NRM Program and was co-funded by the Australian and State Governments. To view the documentary, go to: www.youtube.com/watch?v=d9v5DMzm_1o



Ecology of threatened south-western Australian freshwater fishes

A major strategic investment by the WA State NRM Office funded a collaborative project on the ecology and conservation of three threatened freshwater fishes. The study consisted of three nodes led by Stephen Beatty (Little Pygmy Perch), David Morgan (Balston's Pygmy Perch) and Paul Close (UWA) (Western Trout Minnow) and was a true collaborative effort over the past two years sampling more than 80 sites.

Key findings included: (1) determining the life-cycle, migration patterns, and habitat usage of all species; (2) the discovery of new populations of the Little Pygmy Perch (a species only formally described by CFFR in 2013 representing the first new freshwater fish species discovered in south-west Australia in ~40 years) in the Denmark and Kent River systems, greatly expanding its known extent of occurence; (3) obtaining a much better understanding the recruitment patterns and distribution for the Western Trout Minnow; (4) discovering new breeding and nursery habitats for the Balston's Pygmy Perch; (5) discovering that the Western Trout Minnow can 'climb' and 'jump' over instream barriers; (6) conducting the first mark-recapture program to determine population abundances of south-western freshwater fishes in riverine environments; (7) conducting the first ever remote PIT tagging telemetry study of a freshwater fish in Western Australia to determine the movement patterns of the Western Trout Minnow through a vertical slot fishway; (8) assessing and prioritising the threats to all species and formal submission of the Little Pygmy Perch as a threatened species (nominated as ENDANGERED) under the Wildlife Conservation Act.

The enigmatic aestivating Salamanderfish and Black-stripe Minnow in the southern-most wetlands of Western Australia have been the subject of an ecological study funded by a NRM community grant. The study, by Honours student Garry Ogston (supervised by Stephen Beatty, David Morgan and Brad Pusey (U.W.A.)) has revealed alarming declines in the extent of occurence and area of occupancy of both species that will result in both being listed under the EPBC and Wildlife Conservation Act. By examining a range of hydrological and physicochemial variables and undertaking species distribution modelling, the presence of Salamanderfish was shown to be explained by the depth of habitat in winter and that of the Black-stripe Minnow by the degree of habitat connectivity. The findings suggest that recent climate change has severely impacted these species and has highlighted that urgent adaptive management approaches are required to help the survival of these species.

Knowledge is power in the conservation of Balston's Pygmy Perch, one of Western Australia's rarest freshwater fishes

Fish scientists from Murdoch University's Freshwater Fish Group and Fish Health Unit are working on a project to learn more about one of south-west Western Australia's rarest fishes, the Balston's Pygmy Perch (*Nannatherina balstoni*). This species is historically known to occur in freshwater rivers and lakes between the Moore River, north of Perth and Two Peoples Bay near Albany on the south coast. However, its range is declining mainly due to wide scale habitat degradation including salinisation of waterways resulting from land clearing, and destruction of riparian vegetation. Other threats to the species include introduced fish species, the proliferation of migration barriers, ground and surface water abstraction, and ongoing climate change which has resulted in significant rainfall and stream flow reductions since the 1970s.

The project aims to raise awareness of the plight of Balston's Pygmy Perch and other threatened aquatic species in Western Australia's south-west through community events such as the World Fish Migration Day display held at the Margaret River Farmer's Market in May this year. Excursions have also been conducted with students from Northcliffe District High School and four schools in the Margaret River area to teach them about the freshwater biodiversity values in the region, the processes that threaten these species and various ways that such threats can be mitigated.

Complementing the survey efforts, the project also features activities aimed to mitigate threats to Balston's Pygmy Perch through targeted introduced fish control. The project will also feature aerial surveys in a number of catchments to identify and assess barriers to fish migration such as dams, weirs, and road crossings.

The data and recommendations resulting from this project will inform catchment managers of the habitats and populations of Balston's Pygmy Perch that are most at risk, allowing for the prioritisation of sites for protection or rehabilitation. The project is supported by the South West Catchments Council through funding from the Australian Government and will run until mid-2015.

Protecting threatened fishes in the South West Linkages Target Area

The Freshwater Fish Group & Fish Health Unit has carried out research to protect threatened freshwater fishes in south-western Australia, focussing on Balston's Pygmy Perch (*Nannatherina balstoni*). Aims of the project included quantifying the extent of the contemporary distribution of the species by re-surveying historical collection sites, undertaking targeted removal of feral fishes at key sites, and prioritising instream barriers for modification to enhance migrational opportunities for this potamodromous species in three target catchments. Our surveys revealed a dramatic range decline for the species which appears to have been extirpated from the King River, Kalgan River, Turner Brook, Dombakup Brook, Marbelup Brook and Moore River. Feral fish control was undertaken at four key sites, the most notable of which was in Canebrake Pool in the upper Margaret River. This important refuge houses a number of threatened species, including the critically endangered Hairy Marron (*Cherax tenuimanus*) but has recently become infested with the introduced teleost Eastern Gambusia (*Gambusia holbrooki*).

Hundreds of feral Gambusia were removed from this site as part of the project. The project also featured one of the first real-world applications of a barrier prioritisation process that was developed by researchers in the Freshwater Fish Group & Fish Health Unit in 2013. This process involved a combination of desktop review and aerial survey via helicopter to identify and assess instream barriers to fish migration such as dams, weirs and road crossings in the Margaret River, Scott River and Fly Brook catchments. In total, 20 significant fish barriers were assessed and ranked according to priority for consideration of mitigation options to enhance fish migration.

The findings of this study will be valuable to environmental managers in developing a management and recovery plan for Balston's Pygmy Perch in the face of growing threats from climate change, introduced species, habitat degradation, secondary salinisation, water abstraction and river regulation. The project was supported by the South West Catchments Council and funded by the Australian Government's National Landcare Program and the Government of Western Australia.

Baseline survey of key fish refuges in the Margaret River

Margaret River houses a diverse and unique freshwater fauna and is one of the most important conservation priority areas for freshwater fishes and crayfishes in south-western Australia. The Freshwater Fish Group & Fish Health Unit recently surveyed a number of key refuge sites in the catchment and made some alarming discoveries.

The most notable was the complete absence of Western Mud Minnow (*Galaxiella munda*) in samples at sites where it was previously one of the most abundant species. Similarly, Pouched Lamprey (*Geotria australis*) larvae (ammocoetes) were absent at 75% od their histroical sites. These declines are believed to be linked to declining surface flows resulting from climate change and groundwater abstraction.

The other major finding of the survey was the discovery of introduced Eastern Gambusia (*Gambusia holbrooki*) in Canebrake Pool, one of the most important aquatic refuges in the system. This species, which was previously absent from the upper reaches of Margaret River, was one of the most abundant teleosts in Canebrake Pool. Despite their small size, these fish compete with native fishes for habitat and food resources and exhibit highly aggressive fin-nipping behaviour. Over 80% of the Pygmy Perch and Nightfish specimens captured in Canebrake Pool displayed evidence of caudal fin damage resulting from Eastern Gambusia. A road crossing at the upper end of Canebrake Pool appears to be acting as a barrier to the further spread of Eastern Gambusia in Margaret River, but it is feared that the species may be able to bypass the structure in flood conditions or be illegally translocated further upstream.

It is hoped that the data obtained in this survey will form a baseline for ongoing monitoring of aquatic fauna in this important aquatic ecosystem.

The project was supported by the South West Catchments Council and funded by the Australian Government's National Landcare Program and the Government of Western Australia.

Western Australia's newest freshwater fish

In 2013 a new species of freshwater fish for south-western Australia was formally described as *Nannoperca pygmaea* (Little Pygmy Perch). This is the first species described in the region since 1978, and increases the number of endemic fishes of the south-west to 9, with over 80% of the region's freshwater fishes being found nowhere else. The species, at the time, was only known from an area of 0.06 km^2, and it had an uncertain future due to its habitat undergoing increasing secondary salinisation and contained the feral Eastern Mosquitofish (*Gambusia holbrooki*). Members of our group have since found it in other catchments, and we have submitted applications for the species to be formally listed as *ENDANGERED* under State and Federal law.

The Little Pygmy Perch (Nannoperca pygmaea Morgan, Beatty and Adams 2013)

Movement patterns of introduced Goldfish

Goldfish (*Carassius auratus*) have been widely introduced across the globe and feral populations are known to have considerable ecological impacts within the receiving environments. Despite centuries of domestication and its current widespread distribution, there is a dearth of information on the spatial and temporal movement patterns of this species, which limits the understanding of the impacts of introduced populations and hampers the development of effective control measures. The current study examined the movement patterns of an introduced population of *C. auratus* in a regulated south-western Australian river (Vasse River) using passive acoustic telemetry.

The species had a high residency index within the array, although they were highly mobile, with the mean minimum distance travelled within the array for individuals over the study period equalling 81.5 linear river kilometres> This is the total sum of the distances that a fish moved between the acoustic receivers. One fish moved 231.3 km (including 5.4 km in a 24 hour period) during the study. Importantly, *C. auratus* displayed notable seasonal movement patterns including a clear shift to certain habitats during its breeding period, with most individuals being detected in an off-channel wetland during that time. The results of this study have considerable implications for developing control programs for the species, such as targeting connections to off-channel lentic systems during the breeding period.

The project was supported by the Vasse Wonnerup Pest Fish Steering Committee and funded by the Australian Federal Government's Caring for our Country program and Geocatch.

Tracking Bull Sharks in the Kimberley

During 2014 we tagged a number of Bull Sharks with acoustic tags fitted with temperature and depth sensors, that were monitored by 20 acoustic 'listening' stations in the river. This work is part of James Laolada's Honours studies, and is supported by the Nyikina-Mangala Rangers. To date we have investigated their prey, determined that depth utilisation varies between day and night, and that their recruitment is related to discharge. During 2015, we will be downloading the acoustic receivers to determine their movement patterns during the wet season.

Acoustic tracking Green Sawfish

Growing to 7 m, the Green Sawfish (*Pristis zijsron*) is one of the biggest of the world's five sawfish species. Western Australia is also home to four of the world's five species, but until recently, we knew very little of the the biology, ecology, or distrubtion of Green Sawfish. With funding through Chevron Australia, and the use of a passive acoustic array, whereby we fitted acoustic transmitters to 40 individuals, we have been able to determine the movement patterns and population demographics of the species in the southern Pilbara, and we have discovered a pupping site and nursery ground. We have determined that their home range increases with growth, and our catch per unit effort in the southern Pilbara (near Onslow and the Ashburton River) is the highest reported for any sawfish species; which suggests that this may be an important refuge for this CRITICALLY ENDANGERED species.

Further reading:

Morgan, D.L., Allen, M.G., Ebner, B.C., Whitty, J.M. & Beatty, S.J. (2015). Discovery of a pupping site and nursery for critically endangered Green Sawfish (*Pristis zijsron*). *Journal of Fish Biology* 86: 1658-1663.

Team Sawfish

Team Sawfish has spent 13 years monitoring sawfish populations in the Kimberley. Western Australia is home to four of the world's five sawfish species, and our research is putting WA's sawfish on the world stage. This work has recently appeared on National Geographic's Monster Fish, and Animal Planet's River Monsters, as well as on ABC's Bushwhacked. We greatly appreciate the support of our project partners and funding bodies.

Barriers to sawfish migration

With funding from Chevron Australia administered through the Western Australian Marine Science Institution (WAMSI), Team Sawfish is examining the impact of barriers on sawfish migrations in north-western Australia. The team, in collaboration with the Nyikina-Mangala Rangers in the Fitzroy River, are tracking sawfish with an acoustic array above and below barriers, as well as mapping barriers within the region. We are delighted that Adrian Gleiss was just awarded an ARC DECRA to work with us on the project. We would like to thank the many people and organisations that helped out on the project.

ARC funding to understand the resilience of fishes to climate change

Climate change is threatening biodiversity globally, and fish are no exception. Their ectothermic physiology is responsible for water temperatures having a strong influence on their ability to survive and reproduce. As a result, biologists often turn to physiology to address questions relating to how vulnerable species are to climate change. However, many habitats show significant heterogeneity in temperatures (due to variations in flow, stratification, shading), which in turn provide fishes with the opportunity to thermoregulate. This project aims to identify if fishes can use thermoregulatory behaviour to buffer the effects of climate change. It will use a combination of telemetry, bioenergetics modelling and hydrology with partners from Murdoch, UWA and the University of Melbourne.

This research will initially focus on Freshwater Sawfish and Bull Sharks in the Kimberley, but plans are already in place to expand this work to freshwater systems in the south-west of WA. Both areas are predicted to see substantial changes in climate and understanding the vulnerability of fish within these systems is of critical conservation concern.

Other research

Team Sawfish is also conducting research into the movement patterns of Green Sawfish and Dwarf Sawfish in collaboration with WAMSI, Chevron and CSIRO. For her PhD study, Stacy Blane is using next generation sequencing technologies to study the distribution of adaptively-significant genetic variation in the Freshwater Sawfish. Our group also founded the Sawfish Conservation Society, now an internationally recognised resource for sawfish information and publications.

Further reading:

Morgan, D.L., Allen, M.G., Ebner, B.C., Whitty, J.M. & Beatty, S.J. (2015). Discovery of a pupping site and nursery for critically endangered Green Sawfish (*Pristis zijsron*). *Journal of Fish Biology* 86: 1658-1663.

Whitty, J.M., Phillips, N.M., Thorburn, D.C., Simpfendorfer, C.A., Fielde, I., Peverell, S.C. & Morgan, D.L. (2013). Utility of rostra in the identification of Australian sawfishes (Chondrichthyes: Pristidae). *Aquatic Conservation: Marine and Freshwater Ecosystems*.

Sawfish Conservation Society

SCS

Team Sawfish appeared on Bushwhacked ABC3 in 2014

TEAM SAWFISH

YIMARDOO WARRA RANGERS
NYIKINA MANGALA

Why have so few species of sharks and rays evolved to live in freshwater systems?

Why so few species of elasmobranch have evolved to live in freshwater environments is an age old question. Common thought suggested that osmoregulatory costs may keep sharks at sea, yet some 200 Million years ago, sharks were all but scarce in freshwater systems. In our new paper, we have come up with a new hypothesis, relating to buoyancy control. Sharks and rays use lipid rich livers to provide buoyancy, however the difference in density between oily livers and that of seawater is small, meaning that livers have to be large to provide appreciable buoyancy.

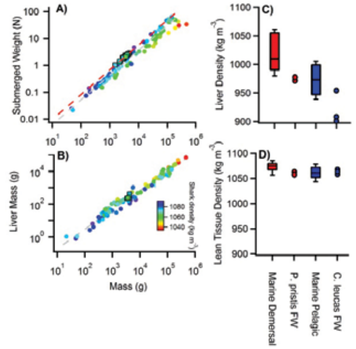
Since the density of freshwater is even lower than that of seawater, this problem is expected to be aggravated. In our work, we modelled the buoyancies of common sharks and found that a simple excursion into freshwater would double negative buoyancy and an 8-fold increase in liver size would be required to offset this change.

To test these predictions we sampled two species of shark naturally occurring in freshwater, the Bull Shark and the Freshwater Sawfish and found that our model predictions were (almost) right; both species had the largest negative buoyancies of any elasmobranch studied to date, yet the liver showed similar size, while its density was slightly lower than comparable species (See Fig.). So why did livers not increase in size to offset this increase in buoyancy?

To address this question, we teamed up with Jean Potvin from St Louis University, a physicist specializing in hydrodynamics of animal locomotion. We found that simple increases in liver size would make animals bulkier, which in turn would increase drag, thus not providing a viable strategy. Overall, our work suggests that living in freshwater comes at increasing metabolic costs to sharks when swimming, these are not faced by bony fish that have a swim-bladder, providing a more efficient source of buoyancy in this group. Interestingly, the majority of elasmobranchs that occur in freshwater are rays and their sedentary lifestyle and propensity to swim close to the substrate would negate the problems faced by sharks swimming in midwater.

Further reading:

Gleiss A.C., Potvin, J., Keleher J.J., Whitty J.M., Morgan D.L. & Goldbogan, J.A. (2015). Mechanical challenges to freshwater residency in sharks and rays. *The Journal of Experimental Biology* 218: 1099-1110.



A) Significant differences were found in the buoyancy of freshwater elasmobranchs we sampled (red line) and those in marine waters (grey line). B) No differences in liver size between individuals sampled in marine environments and those we sampled in freshwater were found. C) Elasmobranchs in freshwater had lower liver densities than their marine counterparts when taking their lifestyle into consideration. D) Lean tissue did not differ between freshwater and marine specimens.

Feral fish control in Western Australia

Researchers with the Centre are actively involved with State government agencies, including the Department of Fisheries and the Swan River Trust, local government and catchment groups in the control of introduced fishes in Western Australia. Some recent examples include the control of Koi Carp (*Cyprinus carpio*) from Sanctuary Waters Estate, Emu Lakes (City of Swan), Studmaster Park (City of Wanneroo) and Woolupine Brook. Many of these waters also contain Goldfish (*Carassius auratus*).

Our staff have also been involved in the control of Pearl Cichlids (*Geophagus brasiliensis*) with the Swan River Trust, as well as the eastern Australian Freshwater Catfish (*Tandanus tandanus*) in Lake Nimbin (Shire of Kalamunda). Murray Cod (*Maccullochella peelii*) were also found in Sanctuary waters. Recently we removed Guppies (*Poecilia reticulata*) from the caves at Exmouth.

Feral fish can have devastating impacts on native aquatic animals and their habitats, and unfortunately, the Pearl Cichlid has now spread into the Canning River system.

A number of introduced parasites and diseases have recently been found in Western Australia as a result of introduced fishes.

You can report feral fish by phoning FishWatch on 1800 815 507

Further reading:

Beatty, S.J. & Morgan, D.L. (2013). Introduced freshwater fishes in a global endemic hotspot and implications of habitat and climatic change. *BioInvasions Records* 2: 1-9.

Beatty, S.J., Morgan, D.L., Keleher, J., Allen, M.G. & Sarre, G.A. (2013). The tropical South American cichlid, *Geophagus brasiliensis* in Mediterranean climatic south-western Australia. *Aquatic Invasions* 8(1): 21-36.

Morgan, D.L., Allen, M.G., Beatty, S.J., Ebner, B.C. & Keleher, J.J. (2014). *A field guide to the freshwater fishes of Western Australia's Pilbara Province.* Freshwater Fish Group, Murdoch University, Murdoch, W.A.

Jawless fishes: 50 years of lamprey research

Lampreys, which are one of the only two surviving groups of jawless fishes (Agnatha), have retained a similar body form for the last 300 million years.

Ian Potter started studying lampreys in 1964 for a PhD at the University of New South Wales. Although he initially aimed just to study the life cycle of the anadromous parasitic species *Mordacia mordax*, based on data collected mainly from the Moruya River on the lower east coast of Australia, he discovered that the lampreys in that river contained a second and very closely-related species. This new species, which was nonparasitic and considered a derivative of *M. mordax*, was given the name *Mordacia praecox*. Although both of these paired species spend a protracted period as larvae (ammocoetes) in freshwater, *M. mordax* subsequently spends a period feeding parasitically at sea, whereas the marine trophic phase has been eliminated in *M. praecox* and sexual maturity is attained in freshwater immediately after the completion of metamorphosis. Ian's PhD thus contained both an ecological component and a taxonomic component, which included a complete revision of the taxonomy of southern hemisphere lampreys.

After completing his PhD, Ian spent a year as a staff member at Duke University in North America, where he worked with Burke Hill on respiration in larval lampreys. He then spent a very stimulating and productive period at Bath University with Martin Hardisty, the doyen of lamprey biology. During that period, he undertook detailed morphological, biochemical and physiological studies aimed at elucidating the trends that have occurred during the evolution of nonparasitic species and continued his work on lamprey respiration. His taxonomic work led Ian to spend a summer with Carl Hubbs at the Scripps Institution of Oceanography where they produced an integrated revision of the lampreys of the northern and southern hemispheres.

While at Bath University, Ian had the pleasure of teaching David Macey and employing David Bird as a research assistant on a lamprey grant, during which they continued Ian's earlier work on paired species. Ian was delighted that the two Davids agreed to come with him to Murdoch University when he became the Foundation Professor of Animal Biology. David Macey undertook a PhD, which involved comparing the oxygen dissociation curves of the blood of the divergent larval and adult stages in the life cycle of the lamprey *Geotria australis*, which is found in south-western Australian rivers. He also discovered that the concentration of iron in the kidneys of larval lampreys was among the highest of all vertebrates. This led to collaboration with Max Cake in which the mechanisms that permitted such iron levels to exist were determined. This provided an excellent model for exploring aspects of the biochemistry and physiology of iron overload in vertebrates in general and thus including humans. David Bird showed that, at the beginning of the upstream spawning migration of *G. australis*, the lipid comprised over 20% of the total body mass and was as high as 25% in the muscle and 40% in the liver. These exceptional levels of lipids, which comprised mainly triacylglycerol, were catabolised as an energy source on the 15 month spawning run, during which the lamprey does not feed.

Rob Hilliard joined the lamprey group in 1977 and remained a crucial member for many years, during which he showed his versatility by working in areas as diverse as the structure and function of the feeding apparatus, intestine, exocrine pancreas, elastin-like fibres in the blood vessels, gonadogenisis and sex differentiation. He also played a major role in demonstrating that the life cycle of *G. australis* comprises a larval phase of 4¼ years, followed by 6 months of metamorphosis, 2 years of feeding parasitically at sea and an upstream migration of 15 months. Rob and Ian greatly appreciated the expert involvement of Dave Pass and Bob Cook in the Vet School in ultrastructural studies of some of the unique anatomical aspects of lampreys.

When Rob Hilliard left, Glenn Power took over his role in the lamprey group and worked with Max Cake and Leon Harris on various aspects of the enzymes of lampreys, demonstrating that the muscle as well as the liver is lipogenic in adult lampreys. Glenn went on later to Oxford on a Rhodes Scholarship, where the excellent biochemical training he had received from Max was put to good effect and he completed his PhD in very good time.

For many years, Ian has worked closely with Helmut Bartels and Ulrich Welch at the University of Munich. The resultant studies enhanced or knowledge of connective tissues and the structure and function of chloride cells in lamprey osmoregulation. Studies undertaken with Shaun Collins at the University of Western Australia have shown that the characteristics of the eyes of the different lamprey families represent adaptations to different life styles. For example, among southern hemisphere lampreys, the eyes of *G. australis* possess an irideal flap that reduces the amount of intraocular flare, a great advantage for a species living in brightly-lit surface waters. In contrast, the eye of *M. mordax* possesses a tapetum, which reflects light back towards the very large photoreceptors and thus represents an adaptation for nocturnal activity.

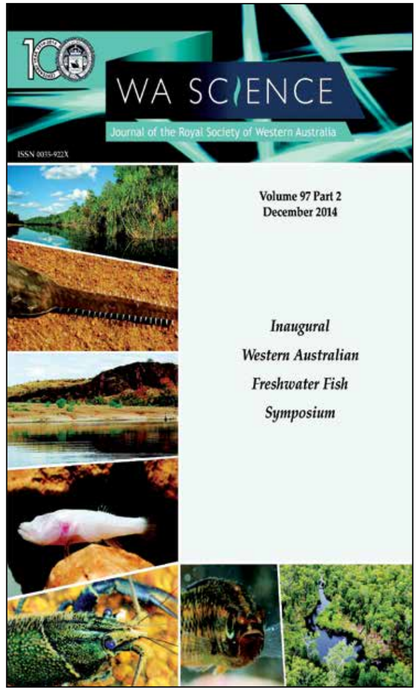
For the last 15 years, Howard Gill, Claude Renaud and Ian have been refining earlier taxonomic schemes for lampreys using both morphological and molecular data. These cladistics studies are being conducted with David Berryman, Frances Brigg and students from Murdoch and crucial colleagues from other universities. From the results thus far, it has been concluded that the current antitropical distribution of lampreys reflects a limited tolerance of high temperatures and the dates of separation and major realignment of the continents during the late Jurassic into the mid-Cretaceous.

Karen Paton is completing her PhD, during which she has studied the metabolic responses of larval and adult lampreys to exhaustive excercise. Her results demonstrate that these responses vary throughout the life cycle and even between males and females at maturity, reflecting adaptations to behavioural changes.

Margaret River lampreys

The biggest threat to the aquatic ecology of the Margaret River comes from climate change, specifically, the declining trend in river flow. A decline in rainfall has led to a significant drop in annual stream discharge (~50%) in the Margaret River since the mid-1970s. Declines in rainfall and stream discharge affects the strength of the upstream migration (from the Indian Ocean) of lampreys. The notable below-average annual rainfall in recent years led to no recruitment in 2012 and 2013, a worrying trend for this ancient species.

We proudly supported the *Inaugural Western Australian Freshwater Fish Symposium*



The Inaugural Western Australian Freshwater Fish Symposium was held at the Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia on the 8th November 2013. The symposium had been conceived as a forum to assist in the conservation and management of the unique fish and crayfish faunas in the inland aquatic systems of Western Australia.

The event was attended by over 100 delegates, mostly from Western Australia, but also included attendees from most other Australian States and Territories. Twenty-eight speakers presented on topics such as threatened species, invasive species, fish parasites, sampling techniques, genetics, morphology, new species discoveries, fish kills, Indigenous Rangers and the management of fishes and their habitats.

We were delighted to have two ASFB stalwarts, Dr Adam Kerezsy and Dr Brendan Ebner, as the Keynote Speakers at the Symposium. The symposium was supported by the Department of Fisheries, Government of Western Australia, Murdoch University's Freshwater Fish Group & Fish Health Unit (Centre for Fish & Fisheries Research), Australian Society for Fish Biology and the Royal Society of WA. The ASFB provided additional financial support for the publication of 11 manuscripts into a Special Issue of the Journal of the RSWA (Volume 97, Part 2, December 2014) in the Royal Society's centenary year.

The manuscripts within the special issue include: a much needed overview of the fishes in fresh waters of Western Australia; a science communication strategy; an overview of the use of underwater video in fresh waters; a review of the critically endangered Hairy Marron; a review of the vulnerable Balston's Pygmy Perch; monitoring of a recently constructed fishway; non-native and native fishes on the Swan Coastal Plain; impacts of secondary salinisation and an estuarine atherinid; as well as three publications on fishes in the Kimberley that relate to harvest of fish, food webs, and the Functional Habitat Concept.

Keynote speaker, Dr Adam Kerezsy (Photography by Tim Bauer/Adam Kerezsy/*Good Weekend*)

Keynote speaker and CFFR Adjunct Researcher, Dr Brendan Ebner (bottom left), with Kimberley Watson (top), deploying baited remote underwater video camera in the Fitzroy River.

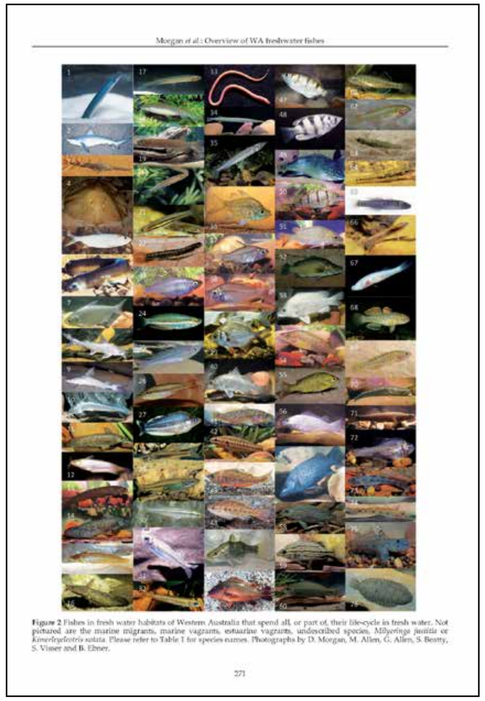
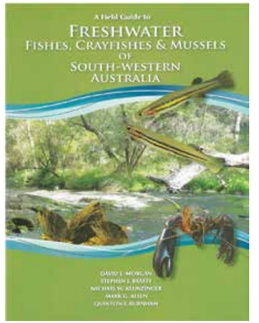


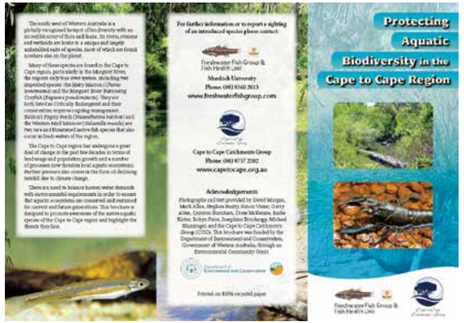
Figure 2 Fishes in fresh water habitats of Western Australia that spend all, or part of, their life-cycle in fresh water. Not pictured are the marine migrants, marine vagrants, estuarine vagrants, undescribed species, *Milyeringa justitia* or *Kimberleyeleotris notata*. Please refer to Table 1 for species names. Photographs by D. Morgan, M. Allen, G. Allen, S. Beatty, S. Visser and B. Ebner.

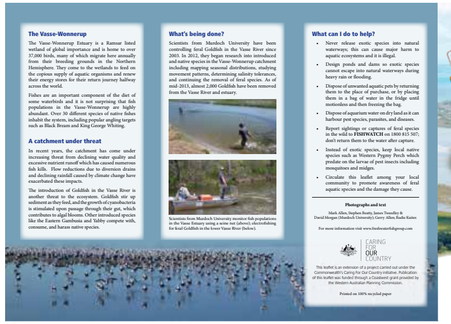
271

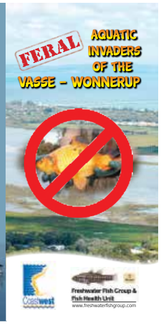
Community outreach

Examples of some of the materials produced by the Freshwater Fish Group as part of our community outreach program.









FISH HEALTH UNIT

Teaching

We provide courses in fish health and production to students in the School of Veterinary and Life Sciences at Murdoch University. We also design and run training courses in Australia and overseas and provide a parasite diagnostic service. We have expertise in fish pathology, parasitology, aquaculture production, genetics and breeding, and environmental management. Recent training courses include a Fish Health Master Class in Bangkok, Thailand in 2007, a Fish Pathology Workshop at Murdoch University, in association with the World Association for Veterinary Parasitology Conference, and a Fish Disease Investigation Master Class in Ho Chi Minh City, Vietnam, in association with the 9th Diseases in Asian Aquaculture Symposium. The Crawford Fund and ACIAR have been generous supporters of our international training programs.

Murdoch Veterinary College students enjoy specialised training in fish health

Students get an opportunity to develop skills in fish disease investigations involving fish handling, anaesthesia, gill and skin biopsies and water chemistry tests as early as in their second year of training. As part of clinical rotations in their final year, greater in-depth knowledge in fish pathology and the art of disease investigations and health management are covered.

There is growing interests among veterinary and life sciences undergraduates in fish health. This is not surprising as there are growing opportunities for employment in the rapidly growing aquaculture sector and related industries in commercial fish feeds and pharmaceuticals, including vaccine production.

In 2014, the Murdoch University Student Chapter of the World Aquatic Veterinary Medical Association (WAVMA) was formed. The first fish disease wet lab was very well attended, with 22 student participants.

It is equally heartening to see an increasing number of our graduates, both from the Veterinary College as well as the School of Veterinary and Life Sciences, coming back to pursue postgraduate degrees in fish health and related disciplines. If you wish to find out more about training opportunities in this field, please contact Dr Susan Gibson-Kueh at S.Kueh@murdoch.edu.au.

Murdoch University Fish Pathology Workshops – vital role in training for aquaculture industry of growing global significance

The overall aim of these workshops is to develop skills in disease recognition in an industry of growing global significance as a means of livelihoods and food security, aquaculture. The first of a series of workshops was the Fish Health Master Class, 12-23 Nov 2007 at the Aquatic Animal Health Research Institute in Bangkok, with 19 participants from 13 Asian countries. This Fish Health Master Class was funded by the ATSE Crawford Fund and the Australian Centre for International Agricultural Research (ACIAR), with additional sponsorship from Intervet Singapore. The full report is available at http://www.crawfordfund.org/wp-content/uploads/2014/03/fishhealth.pdf.

This was followed by a Crawford funded Fish Pathology Workshop held at our excellent multi-header microscope teaching suite, in the School of Veterinary & Life Sciences, Murdoch University, on 22-24 August 2013, with participants from Western Australia, Thailand, and New Zealand.

The latest Crawford funded Fish Disease Master Class was held on 24-25 Nov 2014 at the Ninth Diseases in Asian Aquaculture Symposium (DAA9) conference venue in Ho Chi Minh City, Vietnam. This workshop at DAA9 was attended by 19 participants from 9 countries: Saudi Arabia (1), Singapore (3), Israel (3), Thailand (4), Brunei (1), Vietnam (3), Philippines (1), India (2) and Australia (1). For the full story, please see http://www.crawfordfund.org/news/fish-disease-investigation-goes-digital/

As part of an FRDC project 2009/315:16 People development program: Aquatic animal health training scheme - Boosting Biosecurity Capability in Western Australia with the Aquaculture Council of Western Australia, a series of workshops were held at Indian Ocean Fresh Australia kingfish pilot project farm and Batavia Coast Maritime Institute in Geraldton, a barramundi sea cage farm, Marine Produce Australia, Cone Bay, King's Sound, and Challenger Institute of Technology in Fremantle, between Oct 2011 to Aug 2012. These series of workshops provided fish farm managers and key staff with a set of relevant knowledge and skills on the importance of early disease recognition and appropriate sampling to determine cause of outbreaks. The documents produced as part of this project on fish health management are available on http://www.aquaculturecouncilwa.com/sustainability/aquatic-animal-health/

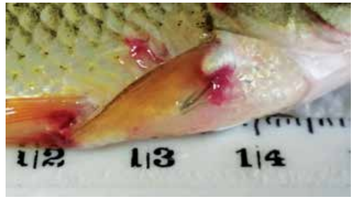
Research projects

An introduced parasite on our native freshwater fishes

Thanks to funding from the Australian and Pacific Science Foundation, the Freshwater Fish Group & Fish Health Unit has been able to conduct research on the introduction of the exotic parasite, *Lernaea cyprinacea*, into our freshwater river systems.

Within Western Australia's Southwestern Province there are only 11 native freshwater species, with 9 limited to this area and many of these are threatened. Our native fish are generally very small in size and so even though they play a significant role in the health of our ecosystem they are often under appreciated. Due to the destructive nature of invasive fish species, particularly with the co-introduction of exotic parasites, having an understanding of their impacts on our freshwater fishes becomes essential in the control and prevention of disease. With the release of goldfish into WA waters has come the co-introduction of *L. cyprinacea*. Unfortunately this parasite appears to have a high impact on the morbidity and mortality rate of our native fishes. Knowing and understanding why becomes crucial in the conservation of our native fishes.

This project is determining the geographic range, prevalence and pathogenicity of the parasite *L. cyprinacea* on native fishes in the south-west. Our research has confirmed that native fish are more readily infected with *Lernaea* than goldfish. Reasons for this appear to be due to a combination of both behavioural and immunological differences. This is not good news for our native fishes as their propensity to become more readily infected means they are also more likely to suffer with higher mortalities. Research on *Lernaea* will continue until September 2015, focusing on the re-infection rates of previously exposed fish, the pathogenicity of infection sites, parasite distribution and intensity of infections. Mikayla McCredden's PhD is progressing well on the introduction of the exotic parasite, *Lernaea cyprinacea*, into our river systems, and the impacts to native fishes. Mikayla is supervised by Alan Lymbery, David Morgan and Stephen Beatty.



Carter's Freshwater Mussel: a threatened species

The freshwater mussel *Westralunio carteri* occurs in freshwater rivers of south-western Australia. It is the only freshwater mussel found in this region, and the only member of the genus *Westralunio* in Australia. The mussel was classified as Vulnerable on the IUCN Red List of threatened species, but was de-listed in 2012.

Michael Klunzinger recently completed his PhD on the ecology of this unique mussel. He described the life-cycle of the mussel for the first time and found that the distribution of *W. carteri* has severely contracted in the last 50 years because of their vulnerability to secondary salinisation and reduced water flow in rivers, the result of climate change. As a consequence, *W. carteri* has now been relisted as Vulnerable by the IUCN and as Threatened under the Western Australian Wildlife Conservation Act.

For more information on MUSSEL WATCH WESTERN AUSTRALIA, go to:
http://www.musselwatchwa.com/

It is one thing to establish that a species is endangered, however, and quite another to develop a plan for its protection. There are still many unanswered questions about the life-cycle and habitat requirements of *W. carteri* that need to be answered before we can develop effective management plans. A new PhD student, Le Ma, is now taking up this challenge.

Further reading:

Klunzinger, M.W., Beatty, S.J., Morgan, D.L., Lymbery, A.J. & Haag, W.R. (2014) Age and growth in the Australian freshwater mussel, *Westralunio carteri*, with an evaluation of the fluorochrome calcein for validating the assumption of annulus formation. *Freshwater Science* 33: 1127-1135.

Klunzinger, M.W., Beatty, S.J., Morgan, D.L., Pinder, A.M. & Lymbery, A.J. (2015) Range decline and conservation status of *Westralunio carteri* (Iredale, 1934) (Bivalvia: Hyriidae) from south-western Australia. *Australian Journal of Zoology*.

Stream salinisation impacts riparian communities

We know that the secondary salinisation of streams and rivers can have a dramatic effect on in-stream flora and fauna. It can also, however, leave a mark on the terrestrial ecosystem adjacent to the stream. Michelle Ingram completed her PhD on this topic, studying experimentally cleared and natural, uncleared catchments of the Collie River in south-western Australia. Michelle found that the diversity of the riparian plant community was reduced at high stream salinities. In turn, this reduced the complexity of the habitat for plant-dwelling invertebrates, leading to a reduction in invertebrate diversity, in particular to a loss of spider species. This is one of the first studies of the cascading effects of stream salinisation on adjacent terrestrial ecosystems.

Further reading:

Doupé, R.G., Lymbery, A.J. & Pettit, N.D. (2006) Stream salinisation is associated with reduced taxonomic, but not functional diversity in a riparian plant community. *Austral Ecology* 32: 388-393.

Parasitism in wild and cultured fishes

Parasites can have a major effect on individual fishes and on fish populations. Melanie Koinari has recently completed her PhD on gastrointestinal protozoans (*Giardia* spp. and *Cryptosporidium* spp.) and anisakid nematodes in fish from aquaculture farms and fish markets in Papua New Guinea, the first time such a study has ever been done. While there was little evidence that parasites were causing health problems in the fish themselves, a number of zoonotic species were identified, posing a potential health risk to fish consumers. We have also continued our work, in collaboration with Una Ryan, on the taxonomy of *Cryptosporidium* spp. found in ornamental fishes in Australia. This is a complex storey, because of the great diversity of parasite genotypes that occur in fishes and the high prevalence. Jacqui Morgan is currently undertaking an Honours project on this topic.

Further reading:

Koinari, M., Karl, S., Elliot, A., Ryan, U.M. and Lymbery, A.J. (2013) Identification of *Anisakis* species (Nematoda: Anisakidae) in marine fish hosts from Papua New Guinea. *Veterinary Parasitology* 193: 126-133.

Koinari, M., Karl, S., Ng-Hublin, J., Lymbery, A.J. and Ryan, U.M. (2013) Identification of novel and zoonotic *Cryptosporidium* species in fish from Papua New Guinea. *Veterinary Parasitology* 198: 1-9.

Lymbery, A.J., Morine, M., Kanani, H.G., Beatty, S.J. & Morgan, D.L. (2014). Co-invaders: The effects of alien parasites on native hosts. *International Journal for Parasitology: Parasites and Wildlife.*

Enteric septicaemia of catfish: *Edwardsiella ictaluri*, a threat to Australia's freshwater fish biodiversity

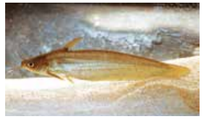
Edwardsiella ictaluri is a bacteria that causes enteric septicaemia and encephalitis, and has caused mass mortality events in wild fish. Catfish species appear to be the most susceptible to *E. ictaluri*, however it can also affect many other fish species. The bacteria has recently been detected in Australia, in captive native catfish held in close proximity to imported ornamental fish. It has not been previously recorded in wild fish in Australia, but could pose a serious threat to our highly endemic fauna.

This project is funded by FRDC Aquatic Animal Health Subprogram 2015/050, and has brought together researchers from the Freshwater Fish Group & Fish Health Unit (Murdoch University), CSIRO and TropWATER (James Cook University), Queensland Department of Agriculture, Fisheries and Forestry, Western Australian Department of Agriculture and Food, the Museum and Art Gallery of Northern Territory and Charles Darwin University to sample wild native catfishes from the Logan, Brisbane, Mary, Burnett, Pioneer, Ross, Tully, Barron, and Bloomfield rivers in Queensland, the Ord, Fitzroy and Ashburton rivers in Western Australia, and Rapid Creek and the Daly River in the Northern Territory.

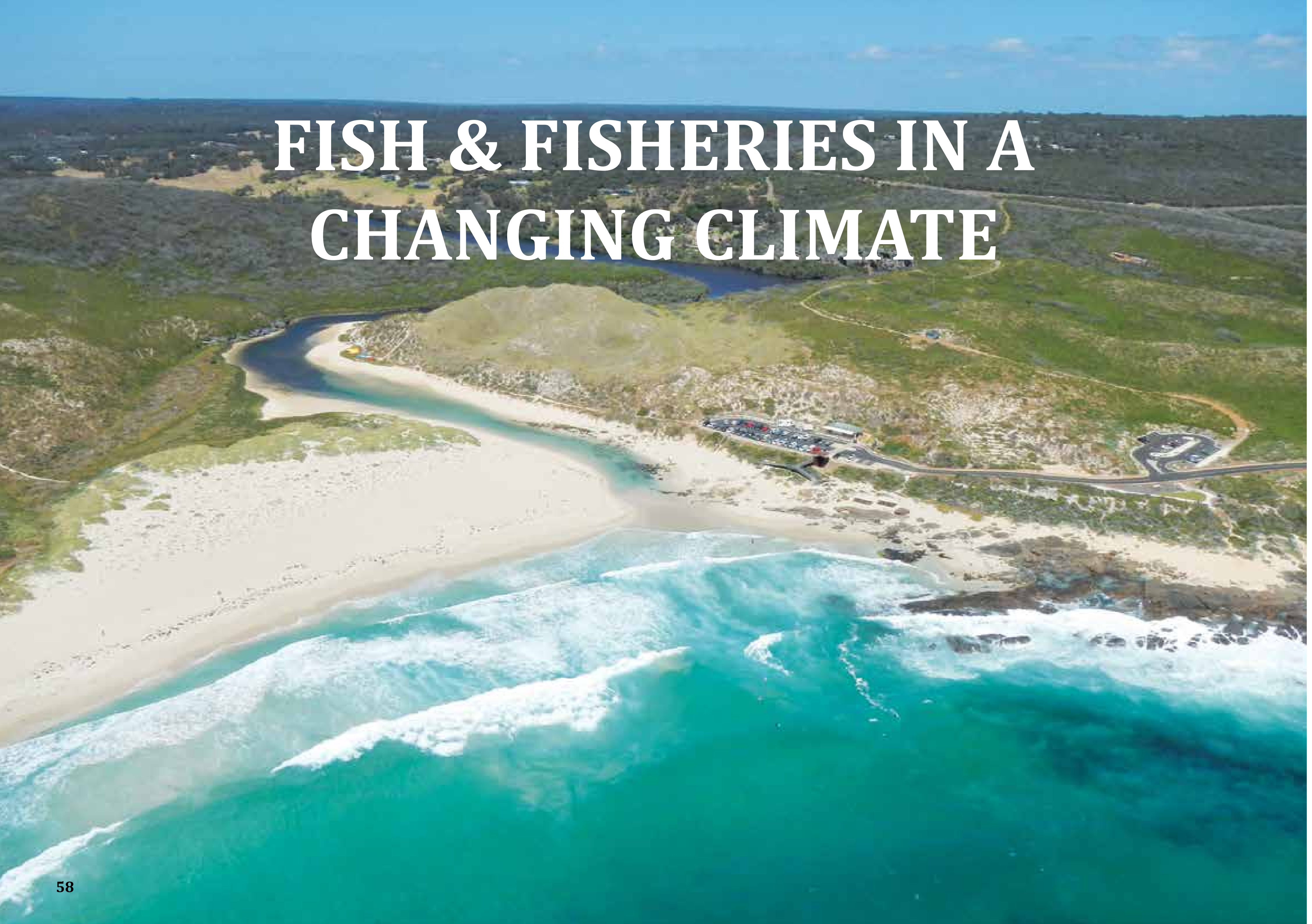
In addition to testing these catfish samples for *E. ictaluri*, tissue samples were also taken to assess the general health of catfish, for parasite studies and to assist in a ranavirus survey with Sydney University.

This has been one of the most extensive surveys of wild native catfish in Australia, in an attempt to determine the presence or absence of this serious bacterial pathogen.

The project forms part of Erin Kelly's Master of Philosophy studies that is supervised by Susan Kueh and Alan Lymbery, with collaborators including David Morgan (Murdoch University), Brendan Ebner, James Donaldson and Terry Miller (CSIRO and TropWATER (JCU)), Aaron Davis and Leo Foyle (James Cook University), Steve Brooks (Qld DAFF), Michael Hammer (MAGNT), Bertus Hanekom, David Crook (CDU), JR Albert (Nyikina-Mangala Rangers), James Keleher (MU) and Nicky Buller and Sam Hair (Department of Agriculture and Food, WA).



FISH & FISHERIES IN A CHANGING CLIMATE



Climate change is of major concern to the sustainability of fish and fisheries in Western Australia. The CFFR has been proactive in examining the impacts of climate change to marine, estuarine and freshwater fishes and their habitats

Drought refuges for freshwater fish

Migration is an important component of the life-cycle of many freshwater fishes in Western Australia and the proliferation of instream barriers in rivers such as dams and weirs impedes these movements and threatens migratory species. The Freshwater Fish Group & Fish Health Unit has recently developed a process for prioritising barriers in southern Australia for remedial works (i.e. decommissioning or modification) in order to enhance fish passage. One of the pioneering elements of the process is the use of helicopters to survey catchments aerially, allowing rapid and cost-effective validation of data on instream barriers and drought refuges. The FFGFHU has undertaken numerous aerial surveys in south-western Australia, surveying over 270 stream kilometres. Barrier prioritisation case studies have been undertaken in six catchments and a number of significant habitats have been discovered that provide drought refuge for some of the State's most endangered fish species.

Giving coastal communities the tools to deal with climate change

A new online planning tool will help coastal communities determine where their strengths and vulnerabilities lie in terms of climate change and give them the knowledge to prepare for the future. The tool on the Coastal Climate Blueprint website, (http://coastalclimateblueprint.org.au/), is the result of four year's work by the University of Tasmania, Murdoch University and CSIRO and is funded by the Fisheries Research and Development Corporation and the Federal Government.
Marine economics expert, Murdoch's Professor Malcolm Tull said the main climate pressures affecting the marine environment in Western Australia are changes in ocean temperatures, the seasonality and location of storms and increasing ocean acidity.

Professor Tull said understanding the effects of changes on fisheries and the marine environment was the first step in helping communities, households, businesses and governments to prepare for the flow-on economic effects of marine climate pressures.

Climate change and potamodromous fishes

There was little understanding of the impact of climate change on potamodromous fishes, and south-western Australia, a hotspot of biodiversity, is now recognised as the canary in the coal mine for examining climate change. The publication by Beatty, Lymbery & Morgan provides a valuable insight into the impacts of climate change on migratory freshwater fishes and the reliance on groundwater in supporting relict freshwater fish populations.

Aestivating fishes

Aestivating fishes have received little attention in regards to the impact of climate change on their habitats and on their requirement to aestivate. A project by Gary Ogston for his Honours degree, which is funded by the State NRM is examining the contemporary distribution of the Gwondwanan relic, the Salamanderfish and the sympatric Black-stripe Minnow in south-western Australia. The study has revealed alarming declines in the extent of occurrences and area of occupancy of both species

Climate change in the Asia-Pacific

The chapter by Roberts, Beckley & Tull in *Climate Change in the Asia-Pacific Region* examines the town of Exmouth in Western Australia to investigate economic strategies for coastal risk mitigation from climate change and extreme weather events. This research offers guidance for developers, local councils and investors in remote coastal regions.

Global Change Biology

Global Change Biology (2014) **20**, 1794–1807, doi: 10.1111/gcb.12444

Implications of climate change for potamodromous fishes

STEPHEN J. BEATTY, DAVID L. MORGAN and ALAN J. LYMBERY
Freshwater Fish Group & Fish Health Unit, School of Veterinary and Life Sciences, Murdoch University, South St Murdoch, WA, Australia

Abstract

There is little understanding of how climate change will impact potamodromous freshwater fishes. Since the mid 1970s, a decline in annual rainfall in south-western Australia (a globally recognized biodiversity hotspot) has resulted in the rivers of the region undergoing severe reductions in surface flows (ca. 50%). There is universal agreement amongst Global Climate Models that rainfall will continue to decline in this region. Limited data are available on the movement patterns of the endemic freshwater fishes of south-western Australia or on the relationship between their life histories and hydrology. We used this region as a model to determine how dramatic hydrological change may impact potamodromous freshwater fishes. Migration patterns of fishes in the largest river in south-western Australia were quantified over a 4 year period and were related to a number of key environmental variables including discharge, temperature, pH, conductivity and dissolved oxygen. Most of the endemic freshwater fishes were potamodromous, displaying lateral seasonal spawning migrations from the main channel into tributaries, and there were significant temporal differences in movement patterns between species. Using a model averaging approach, amount of discharge was clearly the best predictor of upstream and downstream movement for most species. Given past and projected reductions in surface flow and groundwater, the findings have major implications for future recruitment rates and population viabilities of potamodromous fishes. Freshwater ecosystems in drying climatic regions can only be managed effectively if such hydro-ecological relationships are considered. Proactive management and addressing existing anthropogenic stressors on aquatic ecosystems associated with the development of surface and groundwater resources and land use is required to increase the resistance and resilience of potamodromous fishes to ongoing flow reductions.

Keywords: aquatic refuge, freshwater fishes, groundwater reduction, Mediterranean climate, secondary salinization, south-western Australia, surface flow decline

Received 9 May 2013 and accepted 3 October 2013

Introduction

Freshwater ecosystems are in crisis throughout the world. Aquatic habitats associated with 65% of global river flow are moderately or highly threatened, principally by water resource development and pollution (Dudgeon *et al.*, 2006; Vörösmarty *et al.*, 2010). Freshwater fishes are one of the most threatened faunal groups and are expected to be among the most severely impacted by climate change, due to it adding to a wide range of current and future anthropogenic stressors (Ficke *et al.*, 2007; Palmer *et al.*, 2008; Olden *et al.*, 2010; Comte *et al.*, 2013). Freshwater fishes in Mediterranean climatic regions are particularly imperilled and while flow reduction due to water extraction and climate change is recognized as a major threat (Hermoso & Clavero, 2011; Maceda-Veiga, 2013), its impacts are difficult to quantify due to the complexity of abiotic and biotic interactions (Clavero *et al.*, 2010).

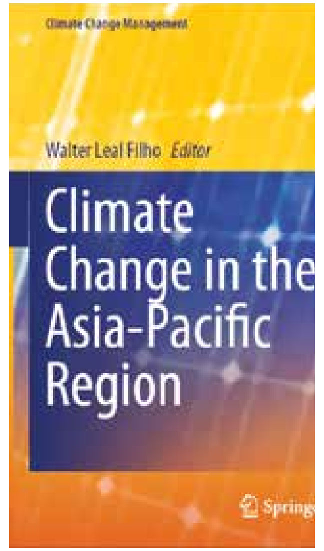
The challenge of conserving critical habitat for freshwater species is exacerbated by life cycles that often involve movement between habitats for different life-history stages (Magoulick & Kobza, 2003) and the linear nature of rivers, whereby upstream activities influence downstream habitat quality and availability (e.g. Gorman & Karr, 1978; Allan *et al.*, 1997). Seasonal migrations in potamodromous fishes are critical for completing life cycles; particularly in accessing spawning and nursery habitats and refugia (Reynolds, 1983; O'Connor *et al.*, 2005; Munz & Higgins, 2013). Understanding refuge use and species mobility is important for enhancing conservation efforts; particularly under drought or flow reduction scenarios (Magoulick & Kobza, 2003; Morán-López *et al.*, 2012; Chessman, 2013).

In comparison to the amount of research on diadromous fishes (e.g. Crozier *et al.*, 2008; Lassalle & Rochard, 2009; Finstad & Hein, 2012; Piou & Prévost, 2013), there is little information on how flow reductions due to climate change will impact potamodromous species (but see Buisson *et al.*, 2008; Clews *et al.*, 2010). The vast majority of research examining the impacts of climate change on freshwater fishes has focussed on salmonids and other cold water species, those with commercial or recreational value, and those in the

Correspondence: Stephen J. Beatty, tel. +618 9360 2813, fax +618 9360 7512, e-mail: s.beatty@murdoch.edu.au

1794

© 2013 John Wiley & Sons Ltd



Further reading:

Beatty, S., Allen, M., Lymbery, A., Storer, T., White, G., Morgan, D. & Ryan, T. (2013). *Novel methods for managing freshwater refuges against climate change in southern Australia: Evaluating small barrier removal to improve refuge connectivity: A global review of barrier decommissioning and a process for southern Australia in a drying climate.* National Climate Change Adaptation Research Facility, Gold Coast, 73 pp. ISBN: 978-1-925039-54-2

Beatty, S., Morgan, D., Keleher, J., Lymbery, A., Close, P., Speldewinde, P., Storer, T. & Kitsios, A. (2013). *Adapting to climate change: A risk assessment and decision making framework for managing groundwater dependent ecosystems with declining water levels, Supporting Document 4: Environmental variables in the habitats of southwestern Australian freshwater fishes: An approach for setting threshold indicator values.* National Climate Change Adaptation Research Facility, Gold Coast, 33 pp. ISBN: 978-1-925039-38-2

Beatty, S.J. & Morgan, D.L. (2013). Introduced freshwater fishes in a global endemic hotspot and implications of habitat and climatic change. *BioInvasions Records* 2: 1-9.

Beatty, S.J., Morgan, D.L. & Lymbery, A.J. (2014). Implications of climate change for potamodromous fishes. *Global Change Biology* 20: 1794-1807.

Chambers, J., Nugent, G., Sommer, B., Speldewinde, P., Neville, S., Beatty, S., Chilcott, S., Eberhard, S., Mitchell, N., D'Souza, F., Barron, O., McFarlane, D., Braimbridge, M., Robson, B., Close, P., Morgan, D., Pinder, A., Froend, R., Horwitz, P., Cook, B. & Davies, P. (2013). *Adapting to climate change: a risk assessment and decision making framework for managing groundwater dependent ecosystems with declining water levels. Development and case studies.* National Climate Change Adaptation Research Facility, Gold Coast. ISBN: 978-1-925039-22-1

Chambers, J., Nugent, G., Sommer, B., Speldewinde, P., Neville, S., Beatty, S., Chilcott, S., Eberhard, S., Mitchell, N., D'Souza, F., Barron, O., McFarlane, D., Braimbridge, M., Robson, B., Close, P., Morgan, D., Pinder. A., Froend, R., Horwitz, P., Cook, B. & Davies, P. (2013). *Adapting to climate change: A risk assessment and decision making framework for managing groundwater dependent ecosystems with declining water levels. Guidelines for use.* National Climate Change Adaptation Research Facility, Gold Coast, 59 pp. ISBN: 978-1-925039-23-8

Metcalf, S.J., van Putten, E. I., Frusher, S., Marshall, N. A., Tull, M., Caputi, N., Haward, M., Hobday, A.J., Holbrook, N.J., Jennings, S.M., Pecl, G. T. & Shaw, J.L. (2015). Measuring the vulnerability of marine social-ecological systems: a prerequisite for the identification of climate change adaptations. *Ecology and Society* 20(2): 35.

Morgan, D.L., Unmack, P.J, Beatty, S.J., Ebner, B.C., Allen, M.G., Keleher, J.J., Donaldson, J.A. & Murphy, J. (2014). An overview of the 'freshwater fishes' of Western Australia. *Journal of the Royal Society of Western Australia* 97: 263-278.

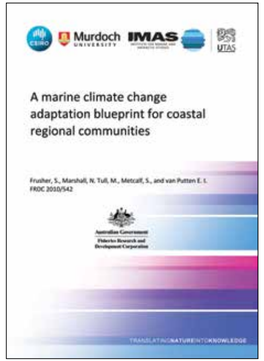
Roberts, R., Beckley, L.E. & Tull, M. (2015). The Economic value of cyclonic storm-surge risks: A hedonic case study of residential property in Exmouth, Western Australia. In: W. Leal Filho (ed.). *Climate Change in the Asia-Pacific Region*. Springer International Publishing, Switzerland. 143-156.

Robson, B.J., Chester, E.T., Allen, M., Beatty, S., Chambers, J.M., Close, P., Cook, B., Cummings, C.R., Davies, P.M., Lester, R., Lymbery, A., Matthews, T.G., Morgan, D. & Stock, M. (2013). *Novel methods for managing freshwater refuges against climate change in southern Australia*. National Climate Change Adaptation Research Facility, Gold Coast, 59 pp. ISBN: 978-1-925039-50-4.

Rountrey, A.N., Coulson, P.G., Meeuwig, J.J. & Meekan, M. (2014). Water temperature and fish growth: otoliths predict growth patterns of a marine fish in a changing climate. *Global change biology* 20: 2450-2458.

Unsworth, R.K.F., van Keulen, M. & Coles, R. (2014). Seagrass meadows in a globally changing environment. *Marine Pollution Bulletin* 83: 383-386.

Van Putten, I., Metcalf, S., Frusher, S.. Marshall, N. & Tull, M. (2014). Fishing for the impacts of climate change in the marine sector: a case study. *International Journal of Climate Change Strategies and Management* 6: 421–441.



PUBLICATIONS

BOOKS

Beatty, S., Allen, M., Lymbery, A., Storer, T., White, G., Morgan, D. & Ryan, T. (2013). *Novel methods for managing freshwater refuges against climate change in southern Australia: Evaluating small barrier removal to improve refuge connectivity: A global review of barrier decommissioning and a process for southern Australia in a drying climate*. National Climate Change Adaptation Research Facility, Gold Coast, 73 pp. ISBN: 978-1-925039-54-2

Beatty, S., Morgan, D., Keleher, J., Lymbery, A., Close, P., Speldewinde, P., Storer, T. & Kitsios, A. (2013). *Adapting to climate change: A risk assessment and decision making framework for managing groundwater dependent ecosystems with declining water levels, Supporting Document 4: Environmental variables in the habitats of southwestern Australian freshwater fishes: An approach for setting threshold indicator values*. National Climate Change Adaptation Research Facility, Gold Coast, 33 pp. ISBN: 978-1-925039-38-2

Chambers, J., Nugent, G., Sommer, B., Speldewinde, P., Neville, S., Beatty, S., Chilcott, S., Eberhard, S., Mitchell, N., D'Souza, F., Barron, O., McFarlane, D., Braimbridge, M., Robson, B., Close, P., Morgan, D., Pinder, A., Froend, R., Horwitz, P., Cook, B. & Davies, P. (2013). *Adapting to climate change: a risk assessment and decision making framework for managing groundwater dependent ecosystems with declining water levels. Development and case studies.* National Climate Change Adaptation Research Facility, Gold Coast. ISBN: 978-1-925039-22-1

Chambers, J., Nugent, G., Sommer, B., Speldewinde, P., Neville, S., Beatty, S., Chilcott, S., Eberhard, S., Mitchell, N., D'Souza, F., Barron, O., McFarlane, D., Braimbridge, M., Robson, B., Close, P., Morgan, D., Pinder. A., Froend, R., Horwitz, P., Cook, B. & Davies, P. (2013). *Adapting to climate change: A risk assessment and decision making framework for managing groundwater dependent ecosystems with declining water levels. Guidelines for use.* National Climate Change Adaptation Research Facility, Gold Coast, 59 pp. ISBN: 978-1-925039-23-8

Christensen, J., & Tull, M. (eds.) (2014). *Historical perspectives on fisheries exploitation in the Indo-Pacific*. Dordrecht: Springer Verlag.

Morgan, D.L., Allen, M.G., Beatty, S.J., Ebner, B.C. & Keleher, J.J. (2014). *A field guide to the freshwater fishes of Western Australia's Pilbara Province*. Freshwater Fish Group & Fish Health Unit, Murdoch University, Murdoch, W.A.

Robson, B.J., Chester, E.T., Allen, M., Beatty, S., Chambers, J.M., Close, P., Cook, B., Cummings, C.R., Davies, P.M., Lester, R., Lymbery, A., Matthews, T.G., Morgan, D. & Stock, M. (2013). *Novel methods for managing freshwater refuges against climate change in southern Australia*. National Climate Change Adaptation Research Facility, Gold Coast, 59 pp. ISBN: 978-1-925039-50-4.

BOOK CHAPTERS

Christensen, J. (2015). To the Islands: Ecological Imperialism on the North-west Australian Coast. In: Gillis, J. & Torma, F. (eds). *Fluid Frontiers: New Currents in Marine Environmental History.* Cambridge: White Horse Press. pp.65-75.

Christensen, J. (2014). Unsettled seas: Towards a history of marine animal populations in the Central Indo-Pacific. In: Christensen, J. & Tull, M. (eds). *Historical perspectives on fisheries exploitation in the Indo-Pacific*. Dordrecht: Springer Science. pp. 13-40.

Christensen, J. & Jackson, G. (2014). Shark Bay Snapper: science, policy, and the decline and recovery of a marine recreational fishery. In: Christensen, J. & Tull, M. (eds). *Historical perspectives on fisheries exploitation in the Indo-Pacific*. Dordrecht: Springer Science. pp. 251-268.

Christensen, J., & Tull, M. (2014). Introduction: historical perspectives of fisheries exploitation in the Indo-Pacific. In: Christensen, J. & Tull, M. (eds). *Historical perspectives on fisheries exploitation in the Indo-Pacific*. Dordrecht: Springer Verlag. pp. 1-12.

Lymbery, A. J. (2015). Aquatic animals. In: Beveridge, I. & Emery, D. (eds). *Australasian Animal Parasites: Inside and Out*. Australian Society for Parasitology. pp. 929-981.

Lymbery, A.J. & Walters, J.A. (2014). Helminth–nematode: anisakid nematodes. In: Motarjemi, Y. (ed.) *Encyclopedia of Food Safety, Volume 2*. Waltham: Academic Press. pp. 78-82.

Momigliano, P., Jaiteh, V. & Speed, C. (2015). Predators in danger: shark conservation and management in Australia, New Zealand, and their neighbours. In: A. Stow, A., Holwell, G. & Maclean, N. (eds). *Austral Ark*. Cambridge: Cambridge University Press. pp. 467-491.

Potter, I.C., Gill, H.S. & Renaud, C.B. (2014). Petromyzontidae: Lampreys. In: Warren, M.L. & Burr, B.M. (eds). *Freshwater fishes of North America*. Baltimore: John Hopkins University Press. pp. 105-139.

Potter, I.C., Gill, H.S., Renaud, C.B. & Haoucher, D. (2015). The taxonomy, phylogeny, and distribution of lampreys. In: Docker, M. (ed.). *Lampreys: Biology, Conservation and Control Volume 1*. Berlin: Springer. pp. 35-73.

Potter, I.C., Warwick, R.M., Hall, N.G., & Tweedley, J.R. (2015). The physico-chemical characteristics, biota and fisheries of estuaries. In: Craig, J. (ed.). *Freshwater Fisheries Ecology.* Wiley-Blackwell. pp. 48-79.

Roberts, R., Beckley, L.E. & Tull, M. (2015). The economic value of cyclonic storm-surge risks: A hedonic case study of residential property in

Exmouth, Western Australia. In: Leal Filho, W. (ed.). *Climate Change in the Asia-Pacific Region*. Springer International Publishing, Switzerland. pp. 143-156.

Tull, M. (2014). History of shark fishing in Indonesia. In: Christensen, J. & Tull, M., (eds.) *Historical perspectives on fisheries exploitation in the Indo-Pacific*. Dordrecht: Springer Verlag. pp. 63-81.

BOOK REVIEW

Beatty, S.J. (2013). Book review: Ecology of Australian Freshwater Fishes P. Humphries & K.F. Walker (2013). CSIRO Publishing, Victoria, Australia. 440 pp. ISBN 9780643097438, price AU $130.00 (hardback). Freshwater Biology DOI: 10.1111/fwb.12251

JOURNAL PUBLICATIONS

2015

Buchanan, P.J. & Beckley, L.E. (2015). Chaetographs of the Leeuwin Current system: oceanographic conditions drive epi-pelagic zoogeography in the south-east Indian Ocean. *Hydrobiologia* DOI 10.1007/s10750-015-2364-4

Celdran, D., Barba, J.I.L., Verduin, J., van Keulen, M. & Atucha, A.A.M. (in press). Linking seed photosynthesis and evolution of the Australian and Mediterranean seagrass genus *Posidonia. PLoS One* PONE-D-15-10954.

Coulson, P.G., Platell, M.E., Clarke, K.R. & Potter, I.C. (2015). Dietary variations within a family of ambush predators (Platycephalidae) occupying different habitats and environments in the same geographical region. *Journal of Fish Biology* 86: 1046-1077.

Dambacher, J.M., Rothlisberg, P.C. & Loneragan, N.R. (2015). Representing fishery and ecosystem dynamics of Australia's Northern Prawn Fishery with qualitative mathematical models. *Ecological Applications* 25: 278-298.

Ebner, B.C., Fulton, C.J. Donaldson, J.A. & Schaffer, J. (2015). Distinct habitat selection by freshwater morays in tropical rainforest streams. *Ecology of Freshwater Fish*.

Feutry, P., Kyne, P.M., Pillans, R. D., Chen, X., Marthick, J., Morgan, D.L. & Grewe, P.M. (in press). Whole mitogenome sequencing refines the population structure of the Critically Endangered sawfish *Pristis pristis* (Linnaeus 1758) in northern Australia. *Marine Ecology Progress Series*.

Gardner, M.J., Chaplin, J.A., Potter, I.C. & Fairclough, D.V. (in press). Pelagic early life stages promote connectivity in the demersal labrid *Choerodon rubescens*. *Journal of Experimental Marine Biology and Ecology*.

Gleiss A.C., Potvin, J., Keleher J.J., Whitty J.M., Morgan D.L. & Goldbogan, J.A. (2015). Mechanical challenges to freshwater residency in sharks and rays. *The Journal of Experimental Biology* 218: 1099-1110.

Hallett, C.S., Valesini, F.J., Clarke, K.R. & Hoeksema, S.D. (in press). Effects of a harmful algal bloom on the community ecology, movements and spatial distributions of fishes in a microtidal estuary. *Hydrobiologia.*

Hipsey, M.R., Hamilton, D.P., Hanson, P.C., Carey, C.C., Coletti, J.Z., Read, J.S., Ibelings, B.W., Valesini, F.J. & Brookes, J.D. (in press). Predicting the resilience and recovery of aquatic systems: a framework for model learning in observatory systems. *Water Resources Research.*

Jaiteh, V. & Momigliano, P. (in press). New distribution records of the vulnerable fossil shark *Hemipristis elongata* from eastern Indonesia call for improved fisheries management. *Marine Biodiversity Records.*

Hordyk, A., Loneragan, N.R. & Prince, J.D. (in press). An evaluation of an iterative harvest strategy for data-poor fisheries using the length-based spawning potential ratio assessment methodology. *Fisheries Research.*

Hordyk, A., Ono, K., Sainsbury, K., Loneragan, N., and Prince, J (2015). Some explorations of the life history ratios to describe length composition, spawning-per-recruit, and the spawning potential ratio. *ICES Journal of Marine Science* 72: 204-216.

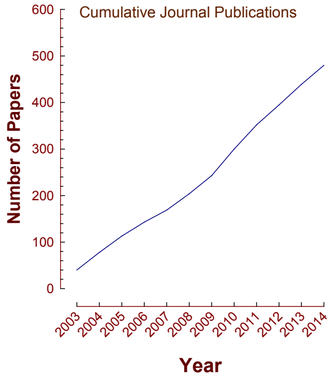
Hordyk, A., Ono, K., Valencia, S., Loneragan, N. & Prince, J (2015). A novel length-based empirical estimation method for the spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. *ICES Journal of Marine Science* 72: 217-231.

Klunzinger, M.W., Haag, W.R., Beatty, S.J., Morgan, D.L. & Lymbery, A.J. (2015). Range decline and conservation status of *Westralunio carteri* Iredale, 1934 (Bivalvia: Hyriidae) from south-western Australia. *Australian Journal of Zoology* 63: 127-135.

Lymbery, A.J. (2015). Niche construction: evolutionary implications for parasites and hosts. *Trends in Parasitology* 31: 134-141.

Lymbery, A.J., Jenkins, E.J., Schurer, J.M. & Thompson, R.C.A. (2015). *Echinococcus canadensis*, *E. borealis*, and *E. intermedius*. What's in a name? *Trends in Parasitology* 31: 23-29.

Metcalf, S.J., van Putten, E. I., Frusher, S., Marshall, N. A., Tull, M., Caputi, N., Haward, M., Hobday, A.J., Holbrook, N.J., Jennings, S.M., Pecl, G. T. & Shaw, J.L. (2015). Measuring the vulnerability of marine social-ecological systems: a prerequisite for the identification of climate change adaptations. *Ecology and Society* 20: 35.



Cumulative number of journal papers since 2003

Momigliano, P. & Jaiteh, V.F. (2015). First records of the grey nurse shark *Carcharias taurus* (Lamniformes: Odontaspididae) from oceanic reefs in the Timor Sea. *Marine Biodiversity Records* 8: e56

Morgan, D.L., Allen, M.G., Ebner, B.C., Whitty, J.M. & Beatty, S.J. (2015). Discovery of a pupping site and nursery for critically endangered Green Sawfish (*Pristis zijsron*). *Journal of Fish Biology* 86: 1658-1663.

Nguyen, H.M., Rountrey, A.N., Meeuwig, J.J., Coulson, P.G., Feng, M., Newman, S.J., Waite, A.M., Wakefield, C.B. & Meekan, M.G. (2015). Growth of a deep-water, predatory fish is influenced by the productivity of a boundary current system. *Scientific Reports* 5.

O'Rorke, R., Jeffs, A.G., Wang, M., Waite, A.M., Beckley, L.E. & Lavery, S.D. (2015). Spinning in different directions: western rock lobster larval condition varies with eddy polarity, but does their diet? *Journal of Plankton Research* 37(3): 542-553.

Potter, I.C., Tweedley, J.R., Elliott, M. & Whitfield, A.K. (2015). The guilds representing the different ways fish use estuaries: a refinement and expansion. *Fish and Fisheries* 16: 230-239.

Prince, J.D., Victor, S., Kloulchad, V.,& Hordyk, A.R. (in press). Length based SPR assessment of eleven Indo-Pacific coral reef fish populations in Palau. *Fisheries Research*.

Prince, J., Hordyk, A., Valencia, S., Loneragan, N. & Sainsbury, K. (2015). Extending the principle of Beverton-Holt Life History Invariants to develop a new framework for borrowing information for data-poor fisheries from the data-rich. *ICES Journal of Marine Science* 72: 194-203.

Ryan, U., Paparini, A., Tong, K., Yang, R., Gibson-Kueh, S., O'Hara, A., Lymbery, A. & Xiao, L. (2015). *Cryptosporidium huwi* n. sp. (Apicomplexa: Eimeriidae) from the guppy (*Poecilia reticulata*). *Experimental Parasitology* 150: 31-35.

Sutarno, Setyawan, A.D. & Lymbery, A.J. (2015). Genetic diversity of five Indonesian native cattle breeds at microsatellite loci. *Asian Journal of Animal Sciences* 9: 57-64.

Sutton, A.L., Beckley, L.E. & Holliday, D. (2015). Euphausiid assemblages in and around a developing anti-cyclonic Leeuwin Current eddy in the south-east Indian Ocean. *Journal of Royal Society of Western Australia* 95.

Tonge, J., Ryan, M., Moore, S.A. & Beckley, L.E. (2014). The effect of place attachment on pro-environment behavioral intentions of visitors to natural area tourist destinations. *Journal of Travel Research* 1-14 doi: 0047287514533010.

Tweedley, J.R. Warwick, R.M. & Potter, I.C. (2015). Can biotic indicators distinguish between natural and anthropogenic environmental stress in estuaries? *Journal of Sea Research* 102: 10-21.

Tweedley, J.R., Hallett, C.S., Warwick, R.M., Clarke, K.R. & Potter, I.C. (in press). The dramatic effect of an extreme weather event on the benthos of a microtidal estuary. *Marine & Freshwater Research*.

Tyne, J.A., Johnston, D.W., Rankin, R., Loneragan, N.R. & Bejder, L. (in press). The importance of spinner dolphin (*Stenella longirostris*) resting habitat: implications for management. *Journal of Applied Ecology.*

Veale, L., Coulson, P.C., Hall, N.G., Hesp, S.A. & Potter, I.C. (2015). Age and size compositions, habitats, growth and reproductive characteristics of a terapontid (*Pelates octolineatus*) in coastal waters. *Marine and Freshwater Research* 66: 535-548.

Veale, L., Coulson, P.C., Hall, N.G. and Potter, I.C. (in press). Biology of a marine-estuarine opportunist fish species in a microtidal estuary, including comparisons among decades and with coastal waters. *Marine and Freshwater Research.*

Wakefield, C.B., Potter, I.C., Hall, N.G., Lenanton, R.C.J. & Hesp, S.A (in press). Marked variations in reproductive characteristics of *Pagrus auratus* (*Chrysophrys auratus*) and their relationship with

temperature over a wide latitudinal range. *ICES Journal of Marine Science.*

Wang, M., O'Rorke, R., Waite, A.M., Beckley, L.E., Thompson, P. & Jeffs, A.G. (2015). Condition of larvae of western rock lobster (*Panulirus cygnus*) in cyclonic and anticyclonic eddies of the Leeuwin Current off Western Australia. *Marine and Freshwater Research* doi.org/10.1071/MF14121.

Webster, F.J., Babcock, R., van Keulen, M. & Loneragan, N.R. (2015). Macroalgae inhibits larval settlement and increases recruit mortality at Ningaloo Reef, Western Australia. *PLoS One* PONE-D-13-34160R2.

Yeo, S. Keesing, J. & van Keulen, M. (2015). Reproductive biology of the sand dollar, *Peronella lesueuri* (L. Agassiz, 1841) (Echinoidea: Clypeasteroida: Laganidae), in south-western Australia. *Invertebrate Reproduction and Development* 2015: 1-14.

2014

Anderson, D.J., Kobryn, H.T., Norman, B.M., Bejder, L., Tyne, J.A. & Loneragan, N.R. (2014). Spatial and temporal patterns of nature-based tourism interactions with whale sharks (*Rhincodon typus*) at Ningaloo Reef, Western Australia. *Estuarine, Coastal and Shelf Science* 148: 109-119.

Baker, R., Buckland, A. & Sheaves, M. (2014). Fish gut content analysis: robust measures of diet composition. *Fish and Fisheries* 15: 170-177.

Beatty, S.J., Morgan, D.L. & Lymbery, A.J. (2014). Implications of climate change for potamodromous fishes. *Global Change Biology* 20: 1794-1807.

Beatty, S.J., Seewraj, K., Allen, M.G. & Keleher, J.J. (2014). Enhancing fish passage over large on-stream dams in south-western Australia: a case study. *Journal of the Royal Society of Western Australia* 97: 313-330.

Clarke, K.R., Tweedley, J.R. & Valesini, F.J. (2014). Simple shade plots aid better long-term choices of data pre-treatment in multivariate assemblage studies. *Journal of the Marine Biological Association of the United Kingdom* 94: 1-16.

Close, P.C., Ryan, T.J., Morgan, D.L., Beatty, S.J. & Lawrence, C.S. (2014). First record of 'climbing' and 'jumping' by juvenile *Galaxias truttaceus* (Valenciennes, 1846) (Galaxiidae) from south-western Australia. *Australian Journal of Zoology*.

Cottingham, A., Hesp, S., Hall, N., Hipsey, M. & Potter, I. (2014). Marked deleterious changes in the condition, growth and maturity schedules of *Acanthopagrus butcheri* (Sparidae) in an estuary reflect environmental degradation. *Estuarine, Coastal and Shelf Science* 149: 109-119.

Coulson, P., Black, B., Potter, I. & Hall, N. (2014). Sclerochronological studies reveal that patterns of otolith growth of adults of two cooccurring species of Platycephalidae are synchronised by water temperature variations. *Marine Biology* 161: 383-393.

Davis, A.M., Unmack, P.J., Pusey, B.J., Pearson, R.G. & Morgan, D.L. (2014). Evidence for a multi-peak adaptive landscape in the evolution of trophic morphology in terapontid fishes. *Biological Journal of the Linnean Society* 113:623-634.

Ebner, B.C., Starrs, D., Morgan, D.L., Fulton, C.J., Donaldson, J.A., Doody, J.S., Cousins, S., Kennard, M., Butler, G., Tonkin, Z., Beatty, S., Broadhurst, B., Clear, R., Lintermans, M. & Fletcher, C.S. (2014). Emergence of field-based underwater video for understanding the ecology of freshwater fishes and crustaceans in Australia. *Journal of the Royal Society of Western Australia* 97: 287-296.

Farrington, L.W., Lintermans, M. & Ebner, B.C. (2014). Characterising genetic diversity and effective population size in one reservoir and two riverine populations of the threatened Macquarie Perch. *Conservation Genetics* 15: 707-716.

Fletcher, L., Coimbra, J., Rodger, J., Potter, I., Gill, H., Dunlop, S. & Collin, S. (2014). Classification of retinal ganglion cells in the Southern Hemisphere lamprey *Geotria australis* (Cyclostomata). *Journal of Comparative Neurology* 522: 750-771.

French, B., Potter, I.C, Hesp, S.A, Coulson, P.G. & Hall, N.G. (2014). Biology of the harlequin fish *Othos dentex* (Serranidae), with particular emphasis on sexual pattern and other reproductive characteristics. *Journal of Fish Biology* 84: 106-132.

Gardner, M., Chaplin, J. & Phillips, N. (2014). Isolation and characterisation of novel microsatellite markers from *Pagrus auratus* and cross amplification in *Acanthopagrus butcheri*. *Conservation Genetics Resources* 6: 155-157.

Hallett, C.S. (2014). Quantile-based grading improves the effectiveness of a multimetric index as a tool for communicating estuarine condition. *Ecological Indicators* 39: 84-87.

Jaiteh, V., Allen, S., Meeuwig, J. & Loneragan, N. (2014). Combining in-trawl video with observer coverage improves understanding of protected and vulnerable species bycatch in trawl fisheries. *Marine and Freshwater Research* 65: 830–837.

Klunzinger, M.W., Haag, W.R., Beatty, S.J., Morgan, D.L. & Lymbery, A.J. (2014). Age and growth in the Australian freshwater mussel, *Westralunio carteri*, with an evaluation of the fluorochrome calcein for validating the assumption of annulus formation. *Freshwater Science* 33: 1127-1135.

Lymbery, A.J., Morine, M., Kanani, H.G., Beatty, S.J. & Morgan, D.L. (2014). Co-invaders: the effects of alien parasites on native hosts. *International Journal for Parasitology: Parasites and Wildlife* 3: 171-177.

Metcalf, S.J., Dambacher, J.M., Rogers, P., Loneragan, N.R. & Gaughan, D.J. (2014). Identifying key dynamics and ideal governance structures for successful ecological management. *Environmental Science and Policy* 37: 34-49.

Metcalf, S.J., van Putten, I., Frusher, S.D, Tull, M. & Marshall, N. (2014). Adaptation options for marine industries and coastal communities using community structure and dynamics. *Sustainability Science* 9: 247–261.

Moore, G. & Chaplin, J. (2014). Contrasting demographic histories in a pair of allopatric, sibling species of fish (Arripidae) from environments with contrasting glacial histories. *Marine Biology* 161: 1543-1555.

Morgan, D.L., Beatty, S.J., Allen, M.G., Keleher, J. & Moore, G. (2014). Long live the King River Perchlet (*Nannatherina balstoni*). *Journal of the Royal Society of Western Australia* 97: 307-312.

Morgan, D., Beatty, S., Snow, M. & Thomas, D. (2014). Preface – Inaugural Western Australian Freshwater Fish Symposium. *Journal of the Royal Society of Western Australia* 97: iii.

Morgan, D.L., Unmack, P.J, Beatty, S.J., Ebner, B.C., Allen, M.G., Keleher, J.J., Donaldson, J.A. & Murphy, J. (2014). An overview of the 'freshwater fishes' of Western Australia. *Journal of the Royal Society of Western Australia* 97: 263-278.

O'Rorke, R., Lavery, S.D., Wang, M., Gallego, R., Waite, A.M., Beckley, L.E., Thompson, P., Jeffs, A.G. (2014). Phyllosomata associated with large gelatinous zooplankton: hitching rides and stealing bites. *ICES Journal of Marine Science* doi:10.1093/icesjms/fsu163

Perez, C.J., Lymbery, A.J. and Thompson, R.C.A. (2014). Chagas disease: the challenge of polyparasitism? *Trends in Parasitology* 30: 176-182.

Rashnavadi, M., Lymbery, A.J., Beatty, S.J. & Morgan, D.L. (2014). Ecological response of an estuarine atherinid to secondary salinisation in south-western Australia. *Journal of the Royal Society of Western Australia* 97: 343-354.

Rountrey, A.N., Coulson, P.G., Meeuwig, J.J., & Meekan, M. (2014). Water temperature and fish growth: otoliths predict growth patterns of a marine fish in a changing climate. *Global change biology* 20: 2450-2458.

Säwstrom, C., Beckley, L., Saunders, M., Thompson, P. & Waite, A. (2014). The zooplankton prey field for rock lobster phyllosoma larvae in relation to oceanographic features of the south-eastern Indian Ocean. *Journal of Plankton Research* 36(4): 1003-1016.

Schwerdtner Máñez, K., Holm, P., Blight, L., Coll, M., MacDiarmid, A., Henn Ojaveer, H., Poulsen, B. & Tull, M. (2014). The future of the oceans past: towards a global marine historical research initiative. *PLoS ONE* 9(7): e101466. doi:10.1371/ journal.pone.0101466.

Starrs, D., Ebner, B.C., Eggins, S.M. & Fulton, C.J. (2014). Longevity in maternal transmission of isotopic marks in a tropical freshwater rainbowfish and the implications for offspring morphology. *Marine and Freshwater Research* 65: 400-408.

Starrs, D., Ebner, B.C. & Fulton, C.J. (2014). All in the ears: unlocking the early life history biology and spatial ecology of fishes. *Biological Reviews* doi:10.111/brv.12162.

Starrs, D., Davis, J.T., Schlaefer, J., Ebner, B.C., Eggins, S.M. & Fulton, C.J. (2014). Maternally transmitted isotopes and their effects on larval fish: a validation of dual isotopic marks within a meta-analysis context. *Canadian Journal of Fisheries and Aquatic Science* 71: 387-397.

Thorburn, D.C., Gill, H.S. & Morgan, D.L., (2014). Predator and prey interactions of fishes of a tropical Western Australia river revealed by dietary and stable isotope analyses. *Journal of the Royal Society of Western Australia* 97: 363-388.

Tonge, J., Ryan, M., Moore, S.A. & Beckley, L.E. (2014). The effect of place attachment on pro-environment behavioral intentions of visitors to natural area tourist destinations. *Journal of Travel Research* doi: 10.1177/0047287514533010.

Tull, M. (2014). Port history in the International Journal of Maritime History (1989-2012). *International Journal of Maritime History* 26: 123-129.

Tweedley, J., Warwick, R., Clarke, R. & Potter, I., (2014). Family-level AMBI is valid for use in the north-eastern Atlantic but not for assessing the health of microtidal Australian estuaries. *Estuarine, Coastal and Shelf Science* 141: 85-96.

Unsworth, R.K.F., van Keulen, M. & Coles, R. (2014) Seagrass meadows in a globally changing environment. *Marine Pollution Bulletin* 83: 383-386.

Valesini, F.J., Tweedley, J.R., Clarke, K.R. & Potter, I.C. (2014). The importance of local, system-wide and regional spatial scales in structuring temperate estuarine fish communities. *Estuaries and Coasts* 37: 525-547.

Van Putten, I., Metcalf, S., Frusher, S.. Marshall, N. & Tull, M. (2014). Fishing for the impacts of climate change in the marine sector: a case study. *International Journal of Climate Change Strategies and Management* 6: 421–441.

Van Putten, I., Metcalf, S., Frusher, S.. Marshall, N. & Tull, M. (2014). Transformation of coastal communities: Where is the marine sector heading? *The Australasian Journal of Regional Studies* 20: 286-324.

Veale, L., Tweedley, J., Clarke, R., Hallett, C. & Potter, I. (2014). Characteristics of the ichthyofauna of a temperate microtidal estuary with a reverse salinity gradient, including inter-decadal comparisons. *Journal of Fish Biology* 85: 1320-1354.

Wang, M., O'Rorke, R., Waite, A., Beckley, L., Thompson, P. & Jeffs, A. (2014). Fatty acid profiles of phyllosoma larvae of western rock lobster (*Panulirus cygnus*) in cyclonic and anticyclonic eddies of the Leeuwin Current off Western Australia. *Progress in Oceanography* 122: 153-162.

2013

Beatty, S.J. & Morgan, D.L. (2013). Introduced freshwater fishes in a global endemic hotspot and implications of habitat and climatic change. *BioInvasions Records* 2: 1-9.

Beatty, S.J., Morgan, D.L., Keleher, J., Allen, M.G. & Sarre, G.A. (2013). The tropical South American cichlid, *Geophagus brasiliensis* in Mediterranean climatic south-western Australia. *Aquatic Invasions* 8: 21-36.

Broadhurst, B.T., Ebner, B.C., Lintermans, M., Thiem, J. D. & Clear, R. (2013). Jailbreak: A fishway releases the endangered Macquarie perch from confinement below an anthropogenic barrier. *Marine and Freshwater Research* 64: 900–908.

Calver, M.C., Beatty, S.J., Bryant, K.A., Dickman, C.R., Ebner, B.C. & Morgan, D.L. (2013). Users beware: implications of database errors when assessing the individual research records of ecologists and conservation biologists. *Pacific Conservation Biology* 19: 320-330.

Ceh, J., Kilburn, M., Cliff, J., Raina, J-B., van Keulen, M. & Bourne, D. (2013). Nutrient cycling in early coral life stages: *Pocillopora damicornis* larvae provide their algal symbiont (*Symbiodinium*) with nitrogen acquired from bacterial associates. *Ecology and Evolution* 3:2393-2400.

Ceh, J., van Keulen, M. & Bourne, D. (2013). Intergenerational transfer of specific bacteria in corals and their implications for offspring fitness. *Microbial Ecology* 65: 227-231.

Davis, A.M., Unmack, P.J., Pusey, B.J., Pearson, R.G. & Morgan, D.L. (2013). Ontogenetic development of intestinal length and relationship to diet in an Australasian fish family (Terapontidae). *BMC Evolutionary Biology* 13: 53.

Davis, A.M., Unmack, P.J., Pusey, B.J., Pearson, R.G. & Morgan, D.L. (2013). Effects of an adaptive zone shift on morphological and ecological diversification in terapontid fishes. *Evolutionary Ecology* 28: 205-227.

Donaldson, J. A., Ebner, B. C. & Fulton, C. J. (2013). Flow velocity underpins microhabitat selectivity in amphidromous gobies of the Australian Wet Tropics. *Freshwater Biology* 58: 1038–105

Ebner, B.C., Fulton, C.J., Cousins, S., Donaldson, J.A., Kennard, M.J., Meynecke, J. & Schaffer, J. (2015). Filming and snorkelling as visual techniques to survey fauna in difficult to access tropical rainforest streams. *Marine and Freshwater Research* 66: 120-126.

Ebner, B.C. & Morgan, D.L. (2013). Using remote underwater video to estimate freshwater fish species richness. *Journal of Fish Biology* 82: 1592-1612.

French, B., Clarke, K. R., Platell, M. E. & Potter, I. C. (2013). An innovative statistical approach to constructing a readily comprehensible food web for a demersal fish community. *Estuarine, Coastal and Shelf Science* 125: 43-56.

Gardner, M., Cottingham, A., Hesp, S., Chaplin, J., Jenkins, G., Phillips, N. & Potter, I. (2013). Biological and genetic characteristics of restocked and wild *Acanthopagrus butcheri* (Sparidae) in a southwestern Australian estuary. *Reviews in Fisheries Science* 21: 441-453.

Gleiss, A.C., Wright, S., Liebsch, N., Wilson, R.P. & Norman, B. (2013). Contrasting diel patterns in vertical movement and locomotor activity of whale sharks at Ningaloo Reef. *Marine Biology* 160: 2981-2992.

Jaiteh, V.J., Allen, S., Meeuwig, J. & Loneragan, N. (2013). Subsurface behavior of bottlenose dolphins (*Tursiops truncatus*) interacting with fish trawl nets in northwestern Australia: Implications for bycatch mitigation. *Marine Mammal Science* 29: 266-281.

Klunzinger, M.W., Jones, H.A., Keleher, J. & Morgan, D.L. (2013). A new record of *Lortiella froggatti* Iredale, 1934 (Bivalvia: Unionoida: Hyriidae) from the Pilbara region, Western Australia, with notes on anatomy and geographic range. *Records of the Western Australian Museum* 28: 1-6.

Klunzinger, M.W., Thomson, G.J., Beatty, S.J., Morgan, D.L. & Lymbery, A.J. (2013) Morphological and morphometrical description of the glochidia of *Westralunio carteri* Iredale, 1934 (Bivalvia: Unionoida: Hyriidae). *Molluscan Research* 33: 104-109.

Kobryn, H.T., Wouters, K., Beckley, L.E. & Heege, T. (2013). Ningaloo Reef: shallow marine habitats mapped using a hyperspectral sensor. *PLoS ONE* 8, e70105.

Koinari, M., Karl, S., Elliot, A., Ryan, U.M. & Lymbery, A.J. (2013). Identification of *Anisakis* species (Nematoda: Anisakidae) in marine fish hosts from Papua New Guinea. *Veterinary Parasitology* 193: 126-133.

Koinari, M., Karl, S., Ng-Hublin, J., Lymbery, A.J. & Ryan, U.M. (2013). Identification of novel and zoonotic Cryptosporidium species in fish from Papua New Guinea. *Veterinary Parasitology* 198: 1-9.

Labbe, A., Dunlop, J. & Loneragan, N. (2013). Central place foraging and feather regrowth rate in bridled terns (*Onychoprion anaethetus*): An insight from stable isotopes. *Marine & Freshwater Research* 64: 1184-1191.

Langdon, M.W., van Keulen, M. & Paling, E.I. (2013). Distribution, abundance and bioerosion of the grazing sea urchin *Echinometra mathaei* at Ningaloo Marine Park, Western Australia. *Journal of the Royal Society of Western Australia* 96: 19.

Loneragan, N., Jenkins, G. & Taylor, M. (2013). Marine stock enhancement, restocking, and sea ranching in Australia: future directions and a synthesis of two decades of research and development. *Reviews in Fisheries Science* 21: 222-236.

Loneragan N.R., Kenyon R.A., Haywood M.D.E., Kangas M., & Caputi N. (2013). Impact of cyclones and macrophytes on the recruitment and landings of tiger prawns, *Penaeus esculentus*, in Exmouth Gulf Western Australia. *Estuarine Coastal and Shelf Science* 127: 46-58.

Lorenzen, K., Agnalt, A., Blankenship, H., Hines, A., Leber, K., Loneragan, N. & Taylor, M. (2013). Evolving context and maturing science: Aquaculture-based enhancement and restoration enter the marine fisheries management toolbox. *Reviews in Fisheries Science* 21: 213-221.

Lymbery, A.J., Kay, G.D., Doupe, R.G., Partridge, G.J. & Norman, H.C. (2013). The potential of a salt-tolerant plant (*Distichlis spicata* cv. NyPa Forage) to treat effluent from inland saline aquaculture and provide livestock feed on salt-affected farmland. *Science of the Total Environment* 445-446: 192-201.

Marr, S.M., Olden, J.D., Leprieur, F., Arismendi, I., Ćaleta, M., Morgan, D.L., Nocita, A., Šanda, R., Serhan Tarkan, A. & García-Berthou, E. (2013). A global assessment of freshwater fish introductions in mediterranean-climate regions. *Hydrobiologia* 719: 317-329.

Moore, G. & Chaplin, J. (2013). Population genetic structures of three congeneric species of coastal pelagic fishes(*Arripis*: Arripidae) with extensive larval, post-settlement and adult movements. *Environmental Biology of Fishes* 96: 1087-1099.

Morgan, D.L., Beatty, S.J. & Adams, M. (2013*). Nannoperca pygmaea*, a new species of pygmy perch (Teleostei: Percichthyidae) from Western Australia. *Zootaxa* 3637: 401-411.

Nivison-Smith, L., Colin, S. P., Zhu, Y., Ready, S., Acosta, M. L., Hunt, D. M., Potter, I. C. & Kalloniatis, M. (2013). Retinal amino acid neurochemistry of the Southern Hemisphere lamprey, *Geotria australis*. *PLOS ONE* 8: 1-19.

O'Shea, O.R., Thums, M., van Keulen, M., Kempster, R.M. & Meekan, M.G. (2013). Dietary partitioning by five sympatric species of stingray (Dasyatidae) on coral reefs. *Journal of Fish Biology* 82: 1805-1820.

Pollock, K., Loneragan, N. & Calver, M. (2013). Fisheries, wildlife, and conservation biology education in Australia: current challenges and future directions. *Australian Zoologist* 36: 413 - 420.

Smallwood, C., Beckley, L. & Moore, S. (2013). Effects of adjacent land tenure on visitor use of Ningaloo Marine Park, Western Australia. *Australasian Journal of Environmental Management* 20: 130-146.

Speed, C.W., Babcock, R.C., Bancroft, K.P., Beckley, L.E., Bellchambers, L.M., Depczynski, M., Field, S.N., Friedman, K.J., Gilmour, J.P., Hobbs, J.-P.A., Kobryn, H.T., Moore, J.A.Y., Nutt, C.D., Shedrawi, G., Thomson, D.P. & Wilson, S.K. (2013). Dynamic stability of coral reefs on the West Australian coast. *PLoS ONE* 8, e69863.

Thompson, R.C.A. & Lymbery, A.J. (2013). Let's not forget the thinkers. *Trends in Parasitology* 29: 581-584.

Starrs, D., Ebner, B.C. & Fulton, C.J. (2013). Can back-calculation models unravel complex larval freshwater fish growth histories? *Journal of Fish Biology* 83: 96–110.

Thiem, J.D., Broadhurst, B.T., Lintermans, M., Ebner, B.C., Clear, R.C. & Wright, D. (2013). Seasonal differences in the diel movements of Macquarie perch (*Macquaria australasica*) in an upland reservoir. *Ecology of Freshwater Fish* 22: 145–156.

Tonge, J., Moore, S., Ryan, M. & Beckley, L. (2013). A photo-elicitation approach to exploring the place meanings ascribed by campers to the Ningaloo coastline, north-western Australia. *Australian Geographer* 44: 143-160.

Tonge, J., Valesini, F.J., Moore, S.A., Ryan, M.M. & Beckley, L.E. 2013. The relation between place attachment and management preferences of visitors at remote coastal campsites in Western Australia. *Visitor Studies* 16: 39-58.

Tweedley, J. R., Bird, D. J., Potter, I. C., Gill, H. S., Miller, P. J., O'Donovan, G. & Tjakrawidjaja, A. H. (2013). Species compositions and ecology of the riverine ichthyofaunas in two Sulawesian islands in the biodiversity hotspot of Wallacea. *Journal of Fish Biology* 82: 1916-1950.

Verduin, J., Seidlitz, A., van Keulen, M. & Paling, E. (2013). Maximising establishment success of *Amphibolis antarctica* seedlings. *Journal of Experimental Marine Biology and Ecology* 449: 57-60.

Walker, K.F., Jones, H.A. & Klunzinger, M.W. (2013). Bivalves in a bottleneck: taxonomy, phylogeography and conservation of freshwater mussels (Bivalvia: Unionoida) in Australasia. *Hydrobiologia* 735: 61-79.

Whitty, J.M., Phillips, N.M., Thorburn, D.C., Simpfendorfer, C.A., Fielde, I., Peverell, S.C. & Morgan, D.L. (2013). Utility of rostra in the identification of Australian sawfishes (Chondrichthyes: Pristidae). *Aquatic Conservation: Marine and Freshwater Ecosystems* 24: 791-804.

Yeo, S., Keesing, J. & van Keulen, M. (2013). Seasonal and diel variation in movement rhythms of sand dollar, *Peronella lesueuri* (Valenciennes 1841), in Cockburn Sound, Western Australia. *Marine Biology* 160: 277-284.

Zieritz, A., Sartori, A.F. & Klunzinger, M.W. (2013). Morphological evidence shows that not all Velesunioninae have smooth umbos. *Journal of Molluscan Studies* 79: 277-282.

OTHER PUBLICATIONS

Beckley, L.E. & Wells, F. (2013). Our modern history 1984-present. *Australian Marine Science Bulletin* No. 190: 16-29.

Hobryn, H.T., Radford, B. & Beckley, L.E. (2014). Ningaloo Reef: easily accessible habitat maps with high spatial and thematic resolution. *Australian Coral Reef Society Newsletter* No 48: 6.

Hood, R., Beckley, L.E., Wiggert, J. & D'adamo, N. (2013). SIBER reaches out to the African research community. *SANCOR Newsletter* No. 201: 7-9.

Morgan, D.L., Mckay, B.,& Beatty, S.J. (2014). History of cichlids in Western Australian aquatic ecosystems. Pp 42-46. In Fulton, W. & Hall, K. (Eds). *Tilapia in Australia-state of knowledge*. 15-16 May 2012, Brisbane. PetSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia.

RESEARCH REPORTS

2015

Allen, M.G., Beatty, S.J. & Morgan, D.L. (2015). *Resurvey of historical collection sites for Balston's Pygmy Perch in the South West Linkages Target Area.* Report to the South West Catchments Council. Freshwater Fish Group & Fish Health Unit, Centre for Fish & Fisheries Research, Murdoch University, Perth, Western Australia.

Allen, M.G., Beatty, S.J. & Morgan, D.L. (2015). *Baseline survey of key fish refuge habitats in the Margaret River*. Report to the Cape to Cape Catchments Group and South West Catchments Council. Freshwater Fish Group & Fish Health Unit, Centre for Fish & Fisheries Research, Murdoch University, Perth, Western Australia.

Beatty, S., Keleher, J. & Allen, M. (2015). *Summary report: Removal of* Tandanus tandanus *from Lake Nimbin, Kalamunda*. Report to the Shire of Kalamunda. Freshwater Fish Group & Fish Health Unit, Centre for Fish & Fisheries Research, Murdoch University, Perth, Western Australia

Keleher, J., Beatty, S. & Allen, M. (2015). *Aquatic fauna of the dams on the Spring Gully Creek watercourse: a rehabilitated mining area in Greenbushes.* Report to the Blackwood Basin Group. Freshwater Fish Group & Fish Health Unit, Centre for Fish & Fisheries Research, Murdoch University, Perth, Western Australia.

Keleher, J., Beatty, S. & Allen, M. (2015). *Summary report: Removal of Goldfish and Koi from the lakes of Studmaster Park, City of Wanneroo*. Report to the City of Wanneroo. Freshwater Fish Group & Fish Health Unit, Centre for Fish & Fisheries Research, Murdoch University, Perth, Western Australia

Valesini, F.J. and Tweedley, J.R. (2015). *Effect of the Becher Point boat ramp on the food resources of Little Penguins on Penguin Island*. Report to the Department of Parks and Wildlife. Murdoch University, Perth, 121 pp.

2014

Allen, M.G., Beatty, S.J., Morgan, D. L. & Keleher, J. (2014). *Feral fish control activities in the South West Linkages Target Area.* Report to the South West Catchments Council. Freshwater Fish Group & Fish Health Unit, Centre for Fish & Fisheries Research, Murdoch University, Perth, Western Australia.

Beatty, S., Allen, M., Keleher, J. & Morgan, D. (2014). *Fishes and crayfishes of Bennett Brook and Whiteman Park.* Report to Whiteman Park. Freshwater Fish Group & Fish Health Unit, Murdoch University, Perth, Western Australia.

Beatty, S., Keleher, J., Morgan, D., Allen, M. & Strehlow, K. (2014). *Aquatic Fauna Survey of Denmark Dam. Report to the Water Corporation of Western Australia*. Freshwater Fish Group & Fish Health Unit, Murdoch University, Perth, Western Australia.

Beatty S.J., Tweedley, J.R., Lymbery, A.J., Keleher, J, Allen, M.G. & Morgan, D.L. (2014). *Introduced and native fishes in the Vasse-Wonnerup Wetland System and its rivers.* Report to the Australian Government through its Caring for our Country Program. Freshwater Fish Group & Fish Health Unit, Centre for Fish & Fisheries Research, Murdoch University, Perth, Western Australia.

Cottingham, A. & Potter, I.C. (2014). *Continuation of the monitoring of restocked and wild Black Bream* Acanthopagrus butcheri *in commercial catches in the Blackwood River Estuary*. Report for the Western Australia Fish Foundation, Murdoch University, Perth, Western Australia

Hallett, C.S. & Tweedley, J.R. (2014). *Assessment of the condition of the Swan Canning Estuary in 2014, based on the Fish Community Indices of estuarine condition*. Report for the Swan River Trust, Murdoch University, Perth, Western Australia. 30 pp.

Keleher, J., Beatty, S., Allen, M. & Morgan, D. (2014). *The Fish and Crayfish Fauna of Yangebup Lake.* Report to the City of Cockburn. Freshwater Fish Group & Fish Health Unit, Murdoch University, Perth, Western Australia.

Morgan, D., Whitty, J., Allen, M., Beatty, S. & Keleher, J. (2014). *Impacts of barriers and fishways on sawfish – Wheatstone sawfish offset December 2014 report*. Freshwater Fish Group & Fish Health Unit, Murdoch University Report to Western Australian Marine Science Institution.

Morgan, D.L., Keleher, J. & Whitty, J. (2014). *Fish fauna associated with Snake (Uralla) Creek, Fitzroy River, Kimberley, Western Australia, 2013 survey*. Freshwater Fish Group & Fish Health Unit (Murdoch University) report to Liveringa Pastoral Co.

Prince, J. & Hordyk, A. (2014) *Independent Sampling Program for Australian Herring in WA.* Biospherics P/L, FRDC Project 2013/061, Fremantle, November 2014

Tweedley, J.R. & Hallett, C.S. (2014). Monitoring the effects of artificial oxygenation on biota in the Swan-Canning Estuary, Western Australia. Report for the Swan River Trust. Murdoch University, Perth, Western Australia. 72pp.

Tweedley, J.R., Keleher, J., Cottingham, A., Beatty, S.J. & Lymbery, A. (2014). *The fish fauna of the Vasse-Wonnerup and the impact of a substantial fish kill event*. Report for Geocatch. Murdoch University, Perth, Western Australia. 113 pp.

Waite, A.M., Beckley, L.E., Jeffs, A., Saunders, M., Sawatrom, C., O'Rorke, R., Raes, E., Thompson, P.A., Feng, M., Caputi, N., Sachlikidis, N., Chan, S., Wang, M., Sutton, A. & Nguyen, H.M. (2014). *Biological oceanography of Western Rock Lobster larvae*. Report to Fisheries Research and Development Corporation. The University of Western Australia, Perth. 126pp.

Whitcraft, S., Hofford, A., Hilton, P., O'Malley, M., Jaiteh, V. & Knights, P. (2014). *Evidence of declines in shark fin demand, China*. *WildAid, San Francisco, CA*.

Williams, J., Cottingham, A. & Potter, I.C. (2014). *Spatial and temporal distribution of spawning by Black Bream (*Acanthopagrus butcheri*) in the Blackwood River Estuary.* Report for the Western Australia Fish Foundation, Murdoch University, Perth, Western Australia

2013

Allen, M.G. (2013). *A rapid reef fish biomass survey of sites in the Raja Ampat Marine Protected Area Network in January-February 2013*. Narrative report to Conservation International Indonesia, 19 pp.

Allen, M.G., Beatty, S.J. & Morgan, D.L. (2013). *Fish survey of Brookfield Estate, Darch Brook & Margaret River: evidence of eradication of goldfish from a Western Australian river.* Report to the Cape to Cape Catchments Group. Freshwater Fish Group & Fish Health Unit, Murdoch University, 6 pp.

Beatty, S.J., Morgan, D.L. & Allen, M.G. (2013). *Assessment of the population sustainability of freshwater fishes and crayfishes of the Angove River, Western Australia: Autumn 2013*. Report to Bio Diverse Solutions. Freshwater Fish Group & Fish Health Unit, Murdoch University, 11 pp.

Beatty, S., Morgan, D., Keleher, J., Allen, M. & Strehlow, K. (2013). *Aquatic fauna of Southampton Pool, Blackwood River: an assessment of the potential impacts during construction of a subterranean pipeline.* Report to the Water Corporation of Western Australia. Freshwater Fish Group & Fish Health Unit, Murdoch University, Perth, Western Australia.

Beatty, S., Morgan, D., Keleher, J., Allen, M. & Strehlow, K. (2013). *Supplementary survey of aquatic fauna of Southampton Pool, Blackwood River: an assessment of the potential impacts during construction of a subterranean pipeline.* Report to the Water Corporation of Western Australia. Freshwater Fish Group & Fish Health Unit, Murdoch University, Perth, Western Australia.

Chambers, J.M., Tweedley, J.R., Clarke, A. & Paice, R. (2013). *Snapshot survey of the distribution and abundance of the macrophytes, macroalgae, phytoplankton and macroinvertebrates of the Vasse-Wonnerup Lagoons January, 2012*. Report for Geocatch. Murdoch University, Perth, Western Australia. 48 pp

French, B., Potter, I.C., Platell, M.E. & Clarke, K.R. (2013). *Determination of the diets of Snapper and Silver Trevally and construction of a food web for the demersal fish community in south-western Australia*. Fisheries Research and Development Corporation Report.

Frusher, S., Marshall, N., Tull, M., Metcalf, S., & van Putten, E. I. (2013). *A marine climate change adaptation blueprint for coastal regional communities*. Hobart, FRDC Project No. 2010/542 November. Fisheries Research and Development Corporation Report.

McLeod, P. B., Christensen, S., McElroy, S., Tull, M. (2013). *Final Report - 2009-081-DLD - Economic assessment of the impact of recent major changes to fisheries management in the WA West Coast demersal wetline fishery*. Project No. 2009/081 April 2013. Fisheries Research and Development Corporation Report.

Morgan, D.L., Beatty, S.J. & Allen, M.G. (2013). *Fishes and crayfishes of Turner Brook: Past and Present.* Report to the Cape to Cape Catchments Group. Freshwater Fish Group & Fish Health Unit, Murdoch University, 15 pp.

Morgan, D.L. & Keleher, J. (2013). *Fish fauna associated with Snake (Uralla) Creek, Fitzroy River, Kimberley, Western Australia, 2012 survey*. Freshwater Fish Group & Fish Health Unit (Murdoch University) report to Liveringa Pastoral Co.

Smallwood, C.B, Hesp, S.A. & Beckley, L.E. (2013). *Biology, stock status and management summaries for selected fish species in south-western Australia*. Fisheries Research Report No. 242. 176pp.

Tweedley, J.R., Chambers, J.M. & Paice, R. (2013). *Sediment accumulation and resuspension in the Vasse-Wonnerup Wetlands and its relationship to internal nutrient cycling*. Report for the South West Catchments Council. Murdoch University, Perth, Western Australia. 54 pp.

Tweedley, J.R. Beatty, S.J., Allen, M. & Lymbery, A.J. (2013). *Increasing community awareness of feral fish in the Vasse-Wonnerup Wetland*. Report for Coastwest. Murdoch University, Perth, Western Australia. 29 pp.

Tweedley, J.R., Beatty, S.J., & Lymbery, A.J. (2013). *Control of introduced fish and crayfish in the Vasse-Wonnerup Ramsar Wetland: Final MERI report*. Report for Caring for our Country. Murdoch University, Perth, Western Australia. 41 pp.

van Keulen, M. (2013). *Monitoring of seagrass transplants into mooring scars in Mangles Bay, southern Cockburn Sound, March 2013*. Prepared for the Cockburn Sound Management Council.

CONFERENCE ABSTRACTS

2015

Beckley, L.E. (2015). Human use data for marine spatial planning and coastal management. *Blue Planet Symposium, Cairns, Australia*.

Beckley, L.E., D'Adamo. N., Hood R., Urban, E. & Wicks, L. (2015). Second International Indian Ocean Expedition (IIOE-2) - emerging science objectives and related planning. *Blue Planet Symposium*, *Cairns, Australia*.

Beckley, L.E., Smallwood, C.B. & Fisher, E.A. (2015). Benchmarking human use of Eighty Mile Beach Marine Park prior to implementation of the management plan. *Western Australian Marine Science Institution Symposium*, *Perth, Australia.*

Sutton, A. & Beckley, L.E. (2015). Influence of oceanography on Kimberley krill assemblages. *Western Australian Marine Science Institution Symposium*, *Perth, Australia*.

Kobryn, H.T., Beckley, L.E. & Gibbons, D. (2015). Spatial distribution of coastal access tracks and trails in the western Kimberley. *Western Australian Marine Science Institution Symposium*, *Perth, Australia*.

2014

Ashworth, E., Hall, N.G., Potter, I.C., Coulson, P.G. & Hesp, S.A. (2014). The patterns of age independent variability between fish length and otolith size among five species of fish. *5th International Otolith Symposium, Spain.*

Beatty, S. &Morgan, D. (2014). Vulnerability of Western Australian fishes to changing flow. In Special Session Fish responses to environmental flows: moving beyond patterns to understand process. *Australian Society for Fish Biology and Australian Society for Limnology Congress, Darwin, June 2014.*

Beckley, L.E. (2014). Australia and the International Indian Ocean Expedition 2: Progress to date. *SCOR International Indian Ocean Expedition scientific plan writing workshop, Bremen, Germany.*

Beckley, L.E. (2014). Revisiting the International Indian Ocean Expedition 110°E line with a process-oriented ecological approach. *International Indian Ocean Expedition 50th Anniversary 3rd Reference Group Meeting, Quatre Bornes, Mauritius.*

Beckley, L.E. (2014). Revisiting the international Indian Ocean Expedition 110°E line with a process oriented, ecological approach. *Australian Marine Sciences Association 51st conference, Canberra, Australia.*

Beckley, L.E. & Clarke, K.R. (2014). Boundary currents in the south Indian Ocean influence taxonomic diversity and distinctness of coastal fishes. *Future Oceans: IMBER Open Science Conference, Bergen, Norway*.

Beckley, L.E., Fisher, E. & Davies, H. (2014). Cumulative visitation by expedition cruise vessels along the remote Kimberley coast. *Australian Marine Sciences Association 51st conference, Canberra, Australia.*

Beckley, L.E., Holliday, D, Sutton, A. & Buchanan, P.J. (2014). Influence of the anomalous Leeuwin Current on macro-zooplankton assemblages in the South-Eastern Indian Ocean. *Future Oceans: IMBER Open Science Conference, Bergen, Norway*.

Beckley, L.E., Smallwood, C.B. & Moore, S.A. (2014). Mapping and analysing human use at Ningaloo Reef, Australia. *Observation et Modelisation Des Activites Humanise en Mer Coterie Seminaire, Brest, France.*

Beckley, L.E. & Van der Elst, R.P. (2014). SW Indian Ocean Fisheries Project: some societal context for IIOE-2.*International Indian Ocean Expedition 50th Anniversary 3rd Reference Group Meeting, Quatre Bornes, Mauritius.*

Bennett, A., Tweedley, J.R., Loneragan, N.R. & Poh, B. (2014). Influence of sediment conditions on the decline of the Western School Prawn (*Metapenaeus dalli*) in a temperate Australian estuary. *12th Australian Marine Science Association (AMSA) Marine Science Student Workshop 2014, Rottnest Island, Australia*.

Bennett, A., Tweedley, J.R., Loneragan, N.R. & Poh, B. (2014). The influence of sediment conditions on the decline of the Western School Prawn (*Metapenaeus dalli*) in a temperate Australian estuary. *2014 Annual Symposium of the Fisheries Society of the British Isles. Hull, United Kingdom.*

Broadley, A., Tweedley, J.R., Poh, B. & Loneragan, N.R. (2014). Estimation of biological parameters for evaluating the success of Western School Prawn (*Metapenaeus dalli*) releases in a temperate Australian estuary. *2014 Annual Symposium of the Fisheries Society of the British Isles. Hull, United Kingdom.*

Crisp, J., Moheimani, N., Tweedley, J.R., D'Souza, F. & Partridge, G. (2014). Larval development and rearing of the Western School Prawn *Metapenaeus dalli* (Racek) in the laboratory. *12th Australian Marine Science Association (AMSA) Marine Science Student Workshop 2014, Rottnest Island, Australia.*

Gibson-Kueh, S. (2014). Diseases of Barramundi: current knowledge and future management strategies. *9th Symposium on Diseases in Asian Aquaculture, Hi Chi Minh City, Vietnam, 24-28 November.*

Jaiteh, V., Warren, C. & Loneragan, N (2014). Building an understanding of the world's biggest shark fishery through fishers' knowledge and participation in scientific data collection. *Sharks International, Durban, South Africa, 2-6 June 2014.*

Jaiteh, V., Warren, C. & Loneragan, N (2014). Sharks, sails and smugglers: Fishing for new livelihoods in Eastern Indonesia. *2nd World Small-Scale Fisheries Congress, Merida, Mexico, 21-26 September 2014.*

Jeffs, A., Wang, M., O'Rorke, R., Waite, A., Beckley, L.E. & Thompson, P.A. (2014). Hot n' hungry lobster larvae: Can a warming ocean explain a decline in spiny lobster recruitment? *10th International Conference and Workshop on Lobster Biology and Management, Cancun, Mexico.*

Kelly, E. , Gibson-Kueh, S., Ebner, B., Donaldson, J., Miller, T., Yang, R., Buller, N., Hair, S., Morgan, D.L. & Lymbery, A.J. (2014). A study of Wet Tropics tandan *Tandanus tropicanus* (Welsh, Jerry & Burrows 2014) from the Bloomfield River, Queensland, Australia. *9th Symposium on Diseases in Asian Aquaculture, Hi Chi Minh City, Vietnam, 24-28 November.*

McCredden, M., Basile, S. & Lymbery, A. (2014). *Lernaea cyprinacea*: An exotic parasite on our native freshwater fish. *International Congress on Parasites of Wildlife Conference, Kruger National Park, South Africa, September 2014.*

Morgan, D., Ramsay, A., Allen, M., Beatty, S. & Keleher, J. (2014). Pilbara fish film and field guide. In Special Session Video techniques and applications in aquatic ecology. *Australian Society for Fish Biology and Australian Society for Limnology Congress, Darwin, Australia, June 2014.*

Morgan, D., Allen, M., Ebner, B., Whitty, J. & Beatty, S. (2014). Detection of juvenile Green Sawfish (*Pristis zijsron*) habitat in Western Australian waters. *Sharks International, Durban, South Africa, 2-6 June 2014.*

Norman, B.M. & Liebsch, N. & Morgan, D.L. (2014). Residency times and movement patterns of whale sharks, *Rhincodon typus*, along the Western Australian coast. *Sharks International, Durban, South Africa, 2-6 June 2014.*

O'Rorke R., Lavery, S., Wang. M., Waite, A., Beckley, L.E., Thompson. P.A. & Jeffs, A. (2014). Hitching rides and stealing bites? Phyllosomas and large gelatinous zooplankton. *10th International Conference and Workshop on Lobster Biology and Management, Cancun, Mexico*.

Paparini, A., Tong, K., Chen, L., Koinari, M., Zangee, N., Reid, A., Morine, M., Lau, J., Ng-Hublin, J., Yang, R., Lymbery, A. & Ryan, U. (2014). Characterization of *Cryptosporidium* in fish. *5th International Giardia & Cryptosporidium Conference, Uppsala, Sweden, May 27-30.*

Poh, B, Tweedley, J.R., Chaplin, J.A., Loneragan, N.R. & Trayler, K. (2014). Monitoring the restocking of the Western School Prawn (*Metapenaeus dalli*) in the Swan-Canning Estuary. *12th Australian Marine Science Association (AMSA) Marine Science Student Workshop 2014, Rottnest Island, Australia.*

Roberts, R., Beckley, L.E. & Tull, M. (2014). Cyclonic storm-surge risk: a hedonic case study of residential property in Exmouth, Western Australia. *Coastal Risks: Hazards, Issues, Representations and Management International Conference, Brest, France.*

Robinson, S., Valesini, F.J., Hipsey, M. & Tweedley, J.R. (2014). Characterising the shifts in benthic macroinvertebrate assemblages in the Swan-Canning Estuary in relation to changing hydrological and biogeochemical conditions. *12th Australian Marine Science Association (AMSA) Marine Science Student Workshop 2014, Rottnest Island, Australia*.

Sutton, A. & Beckley, L.E. (2014). Drivers of krill zoogeography in the Indian Ocean: the implications of poleward flowing boundary currents. *International Biogeography Society Conference, Canberra, Australia*.

Sutton, A. & Beckley, L.E. (2014). Influence of oceanography on the euphausid assemblage of the Leeuwin Current System, south-east Indian Ocean. *15th Southern African Marine Science Symposium, Stellenbosch, South Africa.*

Tweedley, J.R. (2014). Life as post-doc. *12th Australian Marine Science Association (AMSA) Marine Science Student Workshop 2014, Rottnest Island, Australia*.

Tweedley. J.R, Loneragan, N.R., Jenkins, G., Trayler, K. & Chaplin, J.A. (2014). Assessing the decline in western school prawn (*Metapenaeus dalli*) abundance in a temperature Australian estuary: evaluating the effectiveness of prawn releases and the impacts of environmental change. *2014 Annual Symposium of the Fisheries Society of the British Isles, Hull, United Kingdom*.

Tweedley, J.R., Keleher, J., Beatty, S.J. & Lymbery, A. (2014). Fishes of the Vasse-Wonnerup: life in an extreme estuarine environment. *10th Annual Wetland Management Conference, Cockburn, Australia.*

Tweedley, J.R., Beatty, S.J., Lymbery, A. & Ash, A. (2014). Salty Goldfish: Goldfish can use wetlands as 'bridges' to invade new rivers. *10th Annual Wetland Management Conference, Cockburn, Australia.*

Waite, A. M., Jeffs, A., Stemmann, L., Beckley, L. E. & Thompson, P. A. (2014). Rock lobster larval trophic level is impacted by nitrate release from coastally trapped particles within a mesoscale eddy in the eastern Indian Ocean. *AGU, ASLO & TOS Ocean Sciences Meeting, Honolulu, USA*.

Wellington, M., Beckley, L.E. & Sutton, A. (2014). Fishy smorgasbord for seabirds at the Abrolhos Front, south-east Indian Ocean. *Australian Marine Sciences Association 51st conference, Canberra, Australia.*

Whitty, J.M., Morgan, D.L., Gleiss, A., Thorburn, D.C. & Keleher, J. (2014). A review of the Fitzroy River, Western Australia sawfish project and the implications of its findings in regards to anthropogenic disturbances. *Sharks International, Durban, South Africa, 2-6 June 2014.*

Yeoh, D., Valesini, F.J., Williams, J., Abdo, D. & Hallett, C.S. (2014). Tracking movements of three key recreational fish species in a south-western Australian estuary. *Australian Society for Fish Biology and Australian Society for Limnology Conference, Darwin, Australia, June 2014.*

2013

Beatty, S., Morgan, D., Allen, M., Keleher, J. & Lymbery, A. (2013). Vulnerability of south-western Australian fishes to climate change: canaries in the coal mine. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

Beatty, S., Morgan, D., Close, P., Allen, M., Lymbery, A., Davies, R., Ryan, T. & Lawrence, C. (2013). Enhancing the prospects for south-western Australia's rarest and most threatened freshwater fishes. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*.

Beatty, S., Morgan, D. & Tweedley, J.R. (2013). Salted fish: a review of fishes in extreme salinity and how anthropogenic changes in salinity have driven community shifts in Western Australia. *9th Indo-Pacific Fish Conference, Okinawa, Japan.*

Beckley, L.E. (2013). Ongoing and planned research activities relevant to IIOE-2 in 2015-2020: Australia. *International Indian Ocean Expedition 50th Anniversary 2nd Reference Group Meeting, Qingdao, China*.

Beckley, L.E. (2013). AMSA - five decades of shaping the future of marine science in Australia. *Australian Marine Sciences Association Golden Jubilee Conference, Gold Coast, Australia*.

Beckley, L.E. (2013). International Indian Ocean Expedition: Fifty years down the 110° E line. *Australian Marine Sciences Association Golden Jubilee Conference, Gold Coast, Australia*.

Beckley, L.E. (2013). Some ideas for basin-wide compelling science questions for IIOE-2. *International Indian Ocean Expedition 50th Anniversary Reference Group Meeting, Hyderabad, India*.

Beckley, L.E. (2013). 50 years down the line. *International Indian Ocean Expedition 50th Anniversary Reference Group Meeting, Hyderabad, India*.

Beckley, L.E. (2013). Adrift! The secret life of rock lobster larvae. *South West Marine Conference, Dunsborough, Australia*.

Beckley, L.E. (2013). Human use patterns in coastal waters of the western Kimberley. *WAMSI North West Australian Marine Science Symposium, Fremantle, Australia*.

Beckley, L.E. & Holliday, D. (2013). Little fishes and big tides: Larval fish assemblages over a macro-tidal, tropical, continental shelf off the Kimberley, NW Australia. *9th Indo-Pacific Fish Conference, Okinawa, Japan*.

Buchanan, P. J. & Beckley, L.E. (2013). Chaetognatha: distribution and abundance in the Leeuwin Current system. *Australian Marine Sciences Association Golden Jubilee Conference, Gold Coast, Australia.*

Coulson P.G., Black, B.A., Potter, I.C. & Hall, N.G. (2013). Synchronized intra- and interspecific patterns of otolith growth in two cooccurring species of Platycephalidae and their relationships with water temperature. *3rd International Sclerochronology Conference, Caernarfon, North Wales, UK.*

Ebner, B. (2013). A brief history of underwater video survey of Australian freshwater fish assemblages. Keynote Address. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

Holliday, D., Beckley, L.E, Olivar, M.P, Thompson, P.A. & Weller, E. (2013). Spatio-temporal variations of ichthyoplankton over a macro-tidal, tropical continental shelf off the Kimberley, NW Australia. *Australian Marine Sciences Association Golden Jubilee Conference, Gold Coast, Australia.*

Johnson, C.M., Kerr, I., Payne, P., Kobryn, H. & Beckley, L.E. (2013). Crowdsourcing Moby Dick! Modern and historical data identify sperm whale habitat offshore of SW Australia. *Australian Marine Sciences Association Golden Jubilee Conference, Gold Coast, Australia*.

Loneragan, N.R., Jenkins, G., Stagles, I. & Tweedley, J.R. (2013). An overview of restocking and stock enhancement research and a focus on ecological understanding gained from stocking black bream in the Blackwood River. *South West Catchment Council (SWCC) South West Marine Conference 2013, Bunker Bay, Australia*.

Lymbery, A., Hassan, M., Morgan, D. & Beatty, S. (2013). A healthy river is one which is rich in (some) parasites. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

Morgan, D. & Beatty, S. (2013). Western Australia's extreme freshwater fishes. *9th Indo-Pacific Fish Conference, Okinawa, Japan.*

Morgan, D., Beatty, S., Allen, M., Ebner, B. & Keleher, J. (2013). Fishes in freshwaters of Western Australia: an overview. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

Murphy, J., Lymbery A., Beatty, S. & Morgan, D. (2013) Population genetic structure and cryptic speciation within five species of freshwater fish from the south-west of Western Australia. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

Ramsay, A., Morgan, D., Beatty, S., Allen, M., Klunzinger, M.B., Keleher, J. & Robert, J. (2013). Community outreach: field guides and documentaries of Western Australian freshwater fishes. *Inaugural Western Australian Freshwater Fish Symposium, Perth, Western Australia.*

Roberts, R., Beckley, L.E. & Tull, M. (2013). Economic value of cyclonic storm-surge risk: a hedonic case study of residential property in Exmouth, Western Australia. *Australian Marine Sciences Association Golden Jubilee Conference, Gold Coast, Australia*.

Rountrey A.R., Coulson P.G., Feng, M., , Meekan, M., Meeuwig, J.J., Newman, S.J., Nguyen, H.M., Waite, A.M. & Wakefield, C.B. (2013). Otolith chronologies from the southeastern Indian Ocean reveal the effects of temperature and current flow on the growth of fishes in a boundary current ecosystem. *3rd International Sclerochronology Conference, Caernarfon, North Wales, UK.*

Seewraj, K., Beatty, S., Allen, M. & Keleher, J. (2013). Fish passage for on-stream farm dams in the south-west of Western Australia: a large-scale case study. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

Smith, H., Bejder, L., Kobryn, H. & Waples, K. (2013) Space use by bottlenose dolphins in the Leschenault Estuary and Bunbury waters. *3rd Biennial South West Marine Conference, Bunker Bay, Western Australia.*

Starrs, D., Fulton, C. & Ebner, B. (2013). Opportunities to use otoliths for informing Western Australian freshwater fish research and management. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

Sutton, A. & Beckley, L.E. (2013). Drivers of krill zoogeography in the Indian Ocean: the implications of poleward flowing boundary currents. *Australian Marine Sciences Association Golden Jubilee Conference, Gold Coast, Australia*.

Tonge, J., Valesini, F., Moore, S., Beckley, L.E. & Ryan, M. (2013). Place attachment and management preferences of visitors at remote coastal campsites in Western Australia. *Australian Marine Sciences Association Golden Jubilee Conference, Gold Coast, Australia.*

Tweedley, J.R. (2013). My journey: a career in marine biology. *National Youth Science Forum, Perth, Australia*.

Tweedley, J.R., Beatty, S., Lymbery, A., Keleher, J. & Morgan, D. (2013).The fish faunas of the Vasse-Wonnerup: life in an extreme estuarine environment. *South West Catchment Council (SWCC) South West Marine Conference 2013, Bunker Bay, Australia*.

Tweedley, J.R. & Potter, I.C. (2013). *The ways in which fish use estuaries: a refinement and expansion of the guild approach. South West Catchment Council (SWCC) South West Marine Conference 2013, Bunker Bay, Australia*.

Tweedley, J.R. Valesini, F.J., Warwick, R.M., Wildsmith, M.D. & Potter, I.C. (2013). How healthy are estuaries in south-western Australia? Let's ask the benthic invertebrates. *South West Catchment Council (SWCC) South West Marine Conference 2013, Bunker Bay, Australia*.

Veale, L.J., Coulson, P.G., Potter, I.C., Tweedley, J.R., Hallett, C.S. & Hoeksema, S.D. (2013). Shifts in the characteristics of the fish faunas of the Peel-Harvey Estuary in response to anthropogenic and climatic changes. *South West Catchment Council (SWCC) South West Marine Conference 2013, Bunker Bay, Australia*.

Warrington, R.E., Hart, N.S., Davies, W.I.L., Gill, H., Potter, I.C., Hunt, D.M. & Collin, S.P. (2013). Morphological adaptations to different habitats within visual and non-visual light detecting organs in lampreys. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

Centre for Fish & Fisheries Research, Murdoch University, Report 2013-2014

Published by: Centre for Fish & Fisheries Research, Murdoch University
Design & Graphics by David L. Morgan
Photographs provided by members of the Centre for Fish & Fisheries Research
Editors: David Morgan & Fiona Valesini
90 South St
Murdoch
Western Australia, 6150
Ph: +61 89360 6000
Email: fish@murdoch.edu.au
www.murdoch.edu.au/Research-capabilities/Centre-for-Fish-and-Fisheries-Research/

Centre for Fish and Fisheries Research

Murdoch UNIVERSITY

90 South St
Murdoch
Western Australia, 6150
Ph: +61 8 9360 6000
Email: fish@murdoch.edu.au
http://www.murdoch.edu.au/Research-capabilities/Centre-for-Fish-and-Fisheries-Research/