ASFB 2019 Abstracts

1

How to Stand Out and Unleash Your Impact

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1. The University of Adelaide, North Adelaide, SA, Australia

You know that your research can make a positive impact on the world. However, with 7000 new peer-reviewed papers published every day, there is a lot of competition for attention. We are flooded with more papers than we can ever read and cite. In this ocean of papers, how do you get your peers and the public to notice your work? Let alone convince them they should care? In this presentation, Dr Tullio Rossi will paint a vivid picture of how the publishing world is changing and how you can harness emerging tools like graphical and video abstracts to realise the full impact of your research.

2

Illustrating the World's Shark and Ray Species: my unexpected career as a natural history artist."

Lindsay J Marshall[1]

1. Stick Figure Fish Illustration, Peregian Beach, QUEENSLAND, Australia

Abrupt career change is not something we expect as scientists, given the dedication, interest, study, time and effort that we put into our craft. After completing my PhD on illegal fishing and shark fin identification in 2010 I was all set for a career as a scientist. Then, a once in a lifetime invitation completely changed the direction of my professional life. Follow me as I describe how I navigated this change and ended up being the first natural history artist in the last 100 years to illustrate one of the larger extant vertebrate classes in its entirety for the Chondrichthyan Tree of Life Project.

3

Taking science nerdery to the masses

Stella L McQueen[1]

1. New Zealand Native Fish, Wellington, NEW ZEALAND, New Zealand

Are you the sort of scientist that can silence a conversation by suddenly bringing up the anatomical structure of a fish's eyeball, or the parasites in their gills? Ok, maybe your timing is not great, but your enthusiasm and desire to share your topic is the perfect launch-pad into science communication.

You don't have to be an expert and you don't need to be working in a sexy field. You just need the enthusiasm to tell others just how fascinating the minutiae of your field really is. You can leave your serious and objective scientist hat at home. Science communication is the time to break out the pretty pictures, analogies, flowery descriptions, anthropomorphisms, and sheer child-like wonder.

A few pointers: Know your platform – to generate successful content for social media, blogs or radio you also need to be a user of it. Never underestimate the intelligence of your audience, but do put things into everyday language. Don't just spark their curiosity and run – be present and answer their questions.

Perhaps what is holding you back is a fear of things going wrong. If you get something incorrect, correct yourself - people absolutely love honesty and humanity when they have been taught that scientists are cold and aloof. Win your employer over by explaining that you just want to rave about biology, and won't mention locations, clients or projects. And relax, nerding about the structure of fish scales is unlikely to generate a social media pile-on.

4

Scientific illustration for communication and conservation

Erin I Walsh[1]

1. Australian National University | Freelance Artist, Acton, ACT, Australia

Scientific illustration has a long history that is particularly intertwined with biology and conservation. Today, illustration serves as a major pathway for communication within and beyond academia, particularly when it comes to the impacts of human activity and climate change. Against this backdrop, this talk discuss the psychophysical and persuasive pathways that lead to effective visual communication. Focusing on fish, I will use examples from my own practice, and in particular discuss the Conservation Physiology In Action series (https://tinyurl.com/y4z7zhkl).

5

Pathways to impact: saving fish by saving yourself.

Tom Rayner[1]

1. Griffith University, Southport, QLD, Australia

When I quit academia, I didn't know what to do. I knew I was tired, frustrated and miserable. I knew we knew enough to save the world's fish, but I also knew that wasn't happening.

The problem was, I didn't know why. Why were we failing fish? Why wasn't our comms working? Why did it all seem so hard? How could I help make it better? What would that even look like? All I knew was I had to go to the river – I had to ask the fish.

They showed me that sometimes, to save something you love, first you have to save yourself.

6

Reimagining the way we write for bolder and brighter research

Zoe Doubleday[1]

1. University Of South Australia, Adelaide, SA, Australia

Publications are the universal currency for communication among scientists. But they are generally composed of dense, uninspiring language that can be laborious to wade through and difficult to understand. While objectivity and scholarship are indeed cornerstones of scientific writing there is another cornerstone that is rarely emphasised: reader engagement. This has led me to question our current culture of writing and communication and whether it needs an overhaul. Here, I will discuss my research on scientific writing and how we can change the way that we write for a brighter and bolder science future.

7

Participatory GIS mapping for analyzing local peoples' perceptions of environmental change in Madagascar and Solomon Islands.

Shankar S Aswani Canela[1]

1. Rhodes University, Bushmans, EASTERN CAPE, South Africa

In this presentation I draw on geospatial and human ecology research in Madagascar and Solomon Islands to illustrate the incorporation of various dimensions of local/indigenous ecological knowledge and coastal resident behavior into a participatory GIS database. Documenting and incorporating local knowledge systems and associated behavioral patterns into a geospatial database, for subsequent visualization and analysis, can furnish a broader understanding of localized human environmental interactions and environmental impacts, and thus facilitate the design of resource management and conservation programs.

8

Aboriginal values in fish and fishing

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1. Native Title Research Unit, Australian Institute of Aboriginal and Torres Strait Islander Studies, Canberra

2. NSW Aboriginal Fishing Rights Group, Bingie, NSW

3. Questacon - The National Science and Technology Centre, Canberra

For First Nations peoples water is as much part of their Country as land, whether it is saltwater or freshwater. Their customary aquatic resources are important components of their identities, and access to them is crucial to the health, wealth and well-being of their communities.

Between 2015 and 2017, the Australia Institute of Aboriginal and Torres Strait Islander Studies ran the 'Livelihood values of Indigenous customary fishing' project, which sought to identify cultural, social and economic values in Indigenous fishing, and support the recognition of Indigenous fishing values in fisheries management.

In three case study regions - the South Coast of New South Wales, the Far West Coast of South Australia, and the Crocodile Islands in the Northern Territory - the project team worked with local partners to conduct qualitative interviews with a total of 169 Aboriginal people, either individually or in small groups. The interviews covered values in fishing, existing barriers to fishing practices and people's fishing aspirations. While the details often varied between case studies, there were a large number of general values that were shared across all three regions. The results demonstrate that for many First Nations communities, fishing is of significant and interconnected cultural, social, economic, physical and mental health value.

This presentation will provide an overview of the key research findings, followed by an exploration of some of the legislative and management barriers to Aboriginal fishing practices and aspirations present on the South Coast of NSW, and the work local Aboriginal people have been doing to assert and protect their values and interests in fisheries.

This research was only possible with funding and support from the Indigenous Reference Group of the Fisheries Research and Development Corporation.

9

Mungindi to the Mouth – Connecting cultures to conserve native fishes

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1. Macquarie University, Sydney, NSW, Australia

2. Fishway Consulting Services , Sydney, NSW, Australia

3. Institute for Land Water and Society, Charles Sturt University, Albury, NSW, Australia

4. CSIRO Land and Water, Adelaide, SA, Australia

In the Aboriginal world view, people and Country (including lands, waterways and seas) are interdependent entities that are intrinsically linked in the landscape through cultural and spiritual significance. There is no separation of nature and culture - the health of the natural environment and cultural wellbeing of Aboriginal people is directly influenced by the health of cultural landscapes. Traditional ecological knowledge is passed down from generation to generation and continues to the present day. Through dispossession and mismanagement of Aboriginal lands and waters, with a disregard for culture, knowledge and understanding, Aboriginal people have witnessed the detrimental effects upon both their people and the environment.

The Barwon-Darling and Murray rivers form an interconnected hydro-ecological and cultural link between the northern and southern regions of the Murray-Darling Basin. This river system, however, has been profoundly impacted by river regulation: i) the Barwon-Darling is subject to extensive flow storage and diversion, which reduces flow pulses, extends zero flow periods and diminishes low flows and flowing water habitats which historically supported riverine biota (e.g. mussels, snails and fish); ii) the lower Murray is altered from a flowing river to a series of connected weirpools, and iii) the estuary has been deprived of freshwater for over 100 years. These fundamental changes have degraded the health of aquatic ecosystems and the well-being of communities. Nevertheless, the reasons for decline are understood and knowledge to resolve these issues is available, but the wherewithal is required.

We suggest a key to rehabilitating this degraded ecosystem is closely integrating cultural knowledge with science in a partnership that facilitates a unified approach to river management. To this end, we provide an example of the synergies between contemporary science and aboriginal culture that provide insights into the ecological function of the Darling River, and a means to quantitatively inform rehabilitation.

10

Re-Connecting people to Country through enhancing local fish communities…

Michael Gilby[1]

1. Victoria. Fisheries Authority, Irymple, VIC, Australia

Victorian Fisheries Authority in partnership with Traditional Owners, Mallee CMA, Recreational Fishers are undertaking a PILOT stocking trial within the Wallpolla (Horseshoe Lagoon) located in North West Victoria that explores *'utilisation of natural managed ephemeral off-stream water bodies as nursery ponds for native fish'* to determine feasibility. This approach is promoted as being less resource intensive and can be managed by local community groups. This work will include:

1. Designing a simple, non-replicated trial.
2. Determining golden perch and/or silver perch fry stocking density. This will be based on full surface area of the lagoon and will be at a level suitable for extended rearing (up to 12 months).
3. Based on pond and dam stocking rates for fingerlings and adjusting as required.
4. Designing simple monitoring plan (sampling parameters and sampling frequency) for water quality, plankton, and fish.

There is 200 megalitres of environmental water guaranteed to be delivered each season (1000 megalitres in total) to Wallpolla Lagoons (120ha high value wetland). This initiative will undertake operations aligned with Regional Catchment Strategies to deliver environmental water and maximise the associated environmental outcomes at the high value site, to enhance native fish populations within the iconic Lindsay–Wallpolla sites in North West Victoria.

On-Country monitoring will take place every two-three months for the duration of the PILOT project and will be coordinated with a series of community engagement events on-site at Wallpolla Horseshoe Lagoon to promote the collaborative partnership project, the events will include bus tours and community fishing events that help 're-connect people to Country', through a community-based approach to monitoring and tracking stocked fish.

Culture – Shared knowledge through story

Economic - Cultural economy, Cultural harvest strategy

Governance/Management - Regulation, Engagement, Access, Employment Entitlement, Capacity

Relationships - Government, Industry, Politics, Broader community
Wellbeing - Spiritual connection to Country.

12

Tuna (freshwater eels) and Māori socioecological systems

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2. Resource Management Unit, Ngati Hau , Hikurangi, New Zealand

3. Te Kuwaha - Centre of Maori Environmental Research, National Institute of Water & Atmospheric Research, Hamilton, New Zealand

Freshwater cultural keystone species are fundamental in the customary practices and identities of Māori communities. Their distribution and abundance are declining, altering the socioecological systems they support. There is no argument regarding the importance of tuna (freshwater eels) in the lives of Māori, where this taonga (highly prized) species permeates, for example, place names, whakataukī (proverbs), pakiwaitara (legends), waiata (songs) and artwork. Throughout Aotearoa-New Zealand tuna populations continue to support valuable customary, commercial, and recreational fisheries. Because of their extensive migrations and relatively long life, tuna are a challenging fishery to manage and restore, notably because the relative importance and interaction between habitat, recruitment, harvest and other pressures have not been quantified. Furthermore, as there are no controls on the life stages of tuna migrating to and from their spawning grounds in the Pacific Ocean, the maintenance and restoration of the tuna fishery has to rely on activities that enhance populations while in freshwater.

Māori are generally unhappy with the way tuna are currently managed in New Zealand as roles and responsibilities for tuna health and wellbeing and the ecosystems supporting populations are spread across a wide range of agencies with no overarching strategy or leadership. Many iwi (tribes) and hapū (sub-tribes) are driving their own regional and catchment-scale initiatives to protect, enhance and restore local tuna populations. The effective integration of Māori values and practices into decision-making and tuna fisheries management requires leadership and a commitment from government agencies to resource, collaborate and build strong, enduring relationships with iwi and hapū. If implemented, we believe this approach would significantly increase the capability and capacity of environmental resource managers (both Māori and non-Māori), which in turn will optimise the restoration of this cultural keystone species.

13

Fuzzy GIS mapping of Yawuru cultural knowledge – some sea country examples

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2. Nyamba Buru Yawuru , Broome, Western Australia , Australia

Drawing on a collaboration between Nyamba Buru Yawuru and the Fenner School of Environment and Society, this presentation explores some of the ways that Geographic Information Science (GIS) techniques, including the application of sketch mapping and fuzzy logic, can be used to generate spatial data on access to aquatic resources and other valued practices within the Yawuru estate. It explores how these techniques can be adapted to better align with Indigenous knowledges and examines how these modelling processes can be combined with local administrative data to support Indigenous community decision making in coastal and urban environments

14

Can we monitor the immense small scale and multi-species fisheries?

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1. IPMA - Instituto Português do Mar e da Atmosfera, Lisbon, PORTUGAL, Portugal

The small scale fishing fleet, SSF, (vessels with Length overall, LOA, lower or equal than 12m) represents a significant fraction of the Portuguese mainland fleet. The SSF fleet is further classified in two fishing segments: “Local” (vessels with LOA ≤ 9 m) and “Coastal” (vessels with LOA]9,12 m[). The fishing vessels belonging to the “Local” segment (most with less than 5 GT) have a main operational area within 1 - 3 nmi while vessels from “Coastal” segment may operate in an area outside 1 nmi if GT < 100 or outside 6 nmi if GT >100.

On the 31st December 2017 there were 6716 boats registered in mainland Portugal, of which 6147 (92%) belong to the SSF fleet. Despite that, not all of these vessels were active, i.e., engaged in fishing. In fact, just 3190 vessels had an active license in 2017, of these 88% were included in the SSF fleet (2818 vessels: 2649 vessels belonging to the “Local” and 169 vessels to the “Coastal” fishing segment).

Although in the EU fleet register DataBase (http://ec.europa.eu/fisheries/fleet/index.cfm) only one fishing gear licence has been assigned to each vessel, all vessels can have more than one fishing gear license. Consequently, SSF fisheries are characteristically multi-gear. The official fishery data, particularly landings are not discriminated by fishing gear and the spatial information on fishing operations is still reduced. Further, due to the variety of the fishing grounds explored by the SSF vessels, as well as, the biodiversity of the fishing grounds, SSF catches are typically multi-species.

The complexity of Portuguese SSF fisheries, the restricted funding available to monitor SSF fisheries and the necessity to provide scientific advice contribute for the necessity of prioritizing scientific research activities and of the adoption of a well-defined cost–benefit framework for SSF fisheries monitoring. The present paper presents some of the approaches already implemented by IPMA at some Portuguese SSF case studies. From the acquired IPMA experience with these case studies it is expected to trigger open discussion and exchange of experiences.

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Using recreational fishing data to monitor the performance of net free zones

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1. Fisheries Queensland, Dutton Park, QLD, Australia

Monitoring recreational fisheries is a central responsibility of fisheries management. Recreational fishing effort and catch rates vary with weather conditions, days of the week and seasons, making them difficult to monitor through time. To address this, Fisheries Queensland has developed a comprehensive boat ramp survey program, which aims to monitor the abundance of important recreational target species using catch rate indices. Fisheries Queensland has also introduced three net-free zones (NFZs), where commercial fishing with nets is not permitted. These NFZs aim to increase the number and size of fish in the region, allowing recreational fishers to catch more and bigger fish. I demonstrate how the data collected by this boat ramp survey program can monitor the performance of NFZs. NFZs are having a positive impact on the psychology of recreational fishers, with fishers in NFZs more satisfied with their fishing trips compared to fishers in reference areas. NFZ fishers also had higher expectations for future trips than fishers in the reference areas. Catch rates in NFZs have not increased relative to the reference areas, but larger Barred Javelin and Barramundi were kept by fishers in Rockhampton. As NFZs age, they might produce stronger effects on recreational fishing catches, but these effects will vary between regions due to the area covered by the NFZ, environmental factors such as floods and drought, and the reproductive and migratory capabilities of the targeted fish and their prey. Fisheries Queensland’s boat ramp survey program is a promising way to monitor recreational fishing and all data is publicly available.

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Using the environment to control nets - Lakes and Coorong Fishery Finfish Harvest Strategy

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2. Fishwell Consulting, Queenscliff, Victoria, Australia

3. SARDI Aquatic Sciences, West Beach, SA, Australia

4. NMAC(SA) PTY LTD, Golden Grove, SA, Australia

5. Independent Econmist, Sydney, NSW, Australia

The South Australian Lakes and Coorong Fishery is a multi-method, multi-species community based fishery that operates within a highly modified, very dynamic environment, recognised internationally for its unique ecological character. Historically managed under biological performance indicators—the core element of a conventional harvest strategy—in 2016, the Lakes and Coorong Fishery harvest strategy was restructured to use

environmental conditions as the primary indicator. This innovative approach acknowledges that environmental processes play a significant role in the Lakes and Coorong Fishery and the availability of fish resources is linked to this. The harvest strategy uses environmental performance indicators to specify the condition of the freshwater (mean annual water level) and estuarine environment (amount of habitat) and the number of nets allowed for the fishing season is set based on the outcomes of these indicators. Secondary biological indicators such as catch per unit of effort and total annual commercial catch are also in place to monitor key species in the fishery. The harvest strategy has been used to set the total allowable commercial effort for the past three years and a formal review will be undertaken in 2019-20.

17

Why are Snapper eggs so important – Adaptive management of Snapper spawning closures

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1. PIRSA, Adelaide, SA, Australia

2. SARDI Aquatic Sciences, West Beach, SA, Australia

Snapper is an iconic fish species that supports an important commercial and recreational fishery in South Australia. For the commercial fishery, licence holders from four different commercial fisheries have access to SA's Snapper stocks and the recreational sector is divided into the general and charter boat sector. Regulations for the commercial and recreational sector involve a suite of input and output controls and have been subject to numerous reviews with restrictions implemented aimed at limiting commercial and recreational fishing catch and effort, as well as reducing the impacts on fish stocks and the broader marine ecosystem.

In 2013, following an extensive consultation process to review of Snapper management arrangements, five Snapper spawning spatial closures were implemented in the northern parts of the gulfs; one in Gulf St Vincent (GSV) and four in Spencer Gulf (SG). These spatial closures were implemented in known spawning areas informed by scientists, recreational and commercial fishers and were to extend the duration of protection of important spawning aggregations, thereby conferring protection for most of the reproduction season.

Having implemented these spatial closures, the South Australian Research and Development Institute (SARDI) Aquatic Sciences through a Fisheries Research and Development Corporation (FRDC) funded Snapper project were able to evaluate the effectiveness of these spatial closures through determining the proportion of eggs encompassed by the closed area. Through a recent targeted stakeholder consultation process these Snapper spawning spatial closures were reviewed, which has led to the following changes to these closures for 2018/19 Snapper spawning season:

- Removing the spatial closure in northern GSV
- Adding two new spatial closures in Southern GSV
- Continuing with the four spatial closures in SG and adding a spatial closure at Point Lowly

Further research has been undertaken during the 2018/19 Snapper spawning season to understand the effectiveness of these spatial closures.

18

Interpreting the results of the first age-based assessment of sea mullet in WA

Kim Smith[1]

1. Fisheries, Department of Primary Industries and Regional Development, NORTH BEACH, WA, Australia

Sea mullet has been fished commercially in south-western WA virtually since European settlement in 1829. Initially, it was an important source of fresh fish for local people. After 1950 it was increasingly used as bait by the WA rock lobster fishery. Since the 1980s commercial effort has been reduced (by licence buy-backs, fishery closures, etc) in the coastal and estuarine fisheries that historically captured sea mullet, and the total catch of this species has declined accordingly. Today the majority of the WA sea mullet catch is taken in the Peel-Harvey Estuary. In 2015 this fishery obtained Marine Stewardship Council (MSC) certification and, as a result, sea mullet is once again being promoted as a food fish in WA.

In 2019, DPIRD undertook the first age-based assessment of the WA sea mullet stock, based on commercial catch sampling in 2017 and 2018. The assessment was primarily undertaken to support the Peel-Harvey fishery and its ongoing MSC certification. Previously, the stock/fishery was assumed to be adequate/sustainable because recent annual catches and fishing effort have been well below historical levels. The results of the 2019 assessment were expected to validate this assumption, but the results were not quite as expected. Findings are difficult to interpret due to lack of baseline data for this stock. An ongoing monitoring program will need to be implemented to resolve the uncertainties. The cost of such a program has to be weighed up against the value of the fishery.

19

Monitoring sharks caught in Queensland's net fisheries

Lenore Litherland[1]

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Information about the quantity, fate and species of sharks that are landed, or caught but not retained, is crucial to help understand fishery performance, and ultimately to help ensure the sustainable harvest of sharks. Under the *Queensland Sustainable Fisheries Strategy 2017-2027*, Fisheries Queensland has developed new monitoring strategies to validate the species composition of sharks caught in commercial netting operations in the East Coast Inshore Fin Fish Fishery (ECIFFF) and the Gulf of Carpentaria Inshore Fin Fish Fishery (GOCIFFF). The first objective of the program is to determine the species composition of the landed catch. Stratified sampling at ports, seafood processors and at-sea is conducted to representatively sample this retained catch of sharks. The second objective is to develop a profile of the non-retained catch of sharks. This is achieved in two ways; conducting a structured questionnaire with net fishers to document fishers' shark discarding behaviour, and, by sampling any non-retained catch of sharks while observing net robs on-board commercial netting vessels. In addition to achieving core objectives, the program has developed a range of tools to assist shark species identification, as well as an extensive library of genetic samples and a photo library of genetically verified animals. This

talk will provide an overview of the first year of monitoring results and discuss the challenges encountered in developing and maintaining a meaningful routine biological monitoring program for this species group.

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Rethinking fishing effort to monitor stocks in a multi-species abalone fishery

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1. SARDI Aquatic Sciences, Henley Beach, SA, Australia

Commercial catch rate is commonly used to monitor fish stocks as a measure of relative abundance. Estimating CPUE is complicated in multi-species fisheries, where only a single effort measure is available for each fishing event. Under such circumstances, if CPUE is used as a management tool, it must effectively distinguish changes in species abundance from targeted fishing behavior.

The South Australian Abalone Fishery targets two quota managed and high value species that are commonly harvested during the same fishing event. Recent spatio-temporal changes in the relative catch of these two species, likely driven by factors other than abundance (e.g. disease, markets), have highlighted the existing CPUE index might be biased by targeted fishing.

To explore this association between species targeting and CPUE, we used three different methods for estimating 'nominal' CPUE. Each method used a different combination of decision rules to allocate fishing effort and exclude non-targeted fishing events. These 'nominal' indices were then compared with two model-based estimates from a GLM and GLMM. The GLM modelled species catch as a fixed factor over the entire times series, while the GLMM modelled species catch as a random slope within each fishing season.

We found two simple decision rules reduced the association between 'nominal' CPUE and catch. Principally, these included assuming equal catchability among the species by allocating effort proportional to catch and excluding non-targeted fishing days. This revised 'nominal' CPUE index also showed greater inter-annual stability, and aligned closely with expectations from the model-based estimates and the abalone industry. While the GLMM was the most effective approach for understanding relative changes in the two target species through time, a paucity of data limits the application of this approach at most spatial scales for highly structured stocks, such as abalone.

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Putting AI to work in Australia's Darwin Harbour

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3. Department of Primary Industry and Resources, Northern Territory Government, Darwin, Northern Territory, Australia

Identifying and counting fish species in murky water filled with deadly predators is a difficult job. But fisheries scientists in the Northern Territory are working on an artificial intelligence project with Microsoft that has incredible potential for marine science around the world. We present a short history of machine learning applied to quantifying fish stock, results and progress using deep learning with Mask R-CNN, and how to extend the work to new species and different locations.

1. https://news.microsoft.com/en-au/features/fishy-business-putting-ai-to-work-in-australias-darwin-harbour/

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Developing a national social and economic survey of recreational fishers: do we have to choose between being robust and cost effective?

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1. Department of Agriculture and Water Resources, Canberra, ACT, Australia

2. Institute for Applied Ecology, University of Canberra, Canberra, ACT, Australia

The Australian Government is committed to undertaking regular national social and economic surveys of recreational fishers. Probability based white pages surveys have been the standard for large scale recreational fishing surveys in Australia for the last two decades. However this type of survey remain costly and year-on-year reductions in white pages listings in Australia has reduced the representativeness of it as a sampling frame. Online survey methods are commonplace, but they often fail to deliver on representativeness and can be highly biased. We have developed an online survey methodology to overcome issues inherent to standard online surveys. In developing the project, data from the previous national survey was used to model how many respondents would be required in each state and territory to provide robust social and economic estimates. The methodology relies on working with concurrent state-wide recreational fishing surveys to determine and correct for inherent biases associated our online survey. This novel approach can overcome what some researchers saw as intractable problems limiting the use of online surveys.

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Streamlining management arrangements in a complex fishery - Western Australia's first fishery with 100% electronic reporting.

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1. Department of Primary Industries and Regional Development (WA), Perth, WA, Australia

Western Australia's (WA) coastal waters, north and south, support a wide range of aquatic organisms which are highly sought-after for marine aquarium displays across Australia and internationally. Collecting fish for the marine aquarium trade is a growing and valuable industry for WA, however strict regulations are in place to ensure the fishery remains sustainable.

In 2018, the WA Marine Aquarium Fish Managed Fishery (MAF) transitioned from a range of management instruments into one consolidated management plan, supported by a Harvest Strategy. The new arrangements simplify management by reducing red tape and includes a formal Integrated Transferable Quota system for key species.

A cornerstone for this fishery's management and compliance was the development of a new Fish Eye electronic reporting system. The MAF Fish Eye was designed to be capable of accounting for the widespread fishing and landing locations as well as the 950+ species targeted. MAF operators are required to report their activities and catch through the online reporting system. This has streamlined reporting requirements and provides greater transparency on quota monitoring and close to real-time data. This assists with compliance monitoring and provide valuable data to for both WA and Federal authorities.

The MAF is the first WA fishery to move into 100% electronic reporting. The new arrangements reinforce that sustainability for this low volume, high-value fishery is of paramount importance and in line with the world's best practice.

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Prioritising clean accessible data as a means to improving fisheries management

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1. Fisheries Queensland, Brisbane, QLD, Australia

Effective fisheries management relies on accurate messages that are easy for the general public to understand. Data collaboration between Government, researchers, industry and stakeholders is the key to improving our understanding and management of fish resources. Improving data availability between the sectors will enable collaboration, however adoption is traditionally low within Australia.

Traditional data management practices within Fisheries Queensland have resulted in non-validated, and therefore low-quality data, reducing the public's trust in the sustainability of fisheries resources, and the effectiveness of fisheries management. The lack of a modern and responsive infrastructure and robust business rules relating to the integration of data sources has resulted in a 'data swamp'. Such an environment causes inconsistent data outputs and limited data sharing with appropriate external entities (such as universities and researchers, other government departments, and industry).

As part of the Queensland Government's Sustainable Fisheries Strategy, Fisheries Queensland is implementing a range of projects to fundamentally improve data quality, data sharing, and the data outputs that we provide, including integrating independent data sources. The validation of fisheries data using independent sources of data is unique across Australian fisheries authorities.

Big (clean) Data really is the new oil, and developing forward-thinking infrastructure that can integrate data seamlessly from a multitude of sources, including the Internet of Things, will allow fisheries management to harness the power of Artificial Intelligence, and Machine Learning, thus increase the efficiency of management tools, and departments. We are approaching this common problem using design thinking, and a human-centred approach. As such, we aim to create a modern and responsive data lake that can be fished by all.

In this talk I will share the results of our multi-faceted approach, and invite feedback regarding the applicability of our outputs.

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The use of information and communications technology (ICT), gyrocopters and drones to improve the monitoring and management of data-poor small-scale fisheries.

Miguel B. Gaspar[1], Fábio Pereira[1], André N. Carvalho[1], David Piló[1], Paula Chainho[2], José L. Costa[2], Paulo Vasconcelos[1]

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Small-scale fisheries (SSF) have a strong representation in mainland Portugal, encompassing more than 80% of the Portuguese fishing fleet. SSF vessels are small (overall length lower than 9m) and operate mostly within 3 nautical miles from the coastline. SSF use a broad combination of fishing gears and techniques, target a wide variety of species with high commercial value, involve a high number of fishermen and traders, and are responsible for most supply of fresh fish products to local seafood markets. Furthermore, SSF promote job creation, livelihoods and population settlement, constituting the socio-economic base of many fishing communities. In addition, SSF have ancestral cultural traditions and involve a high level of knowledge and skills that must be preserved. The SFF are extremely dependent on local and regional resources due to reduced mobility of the fleet. Moreover, SSF are characterized by multi-gear, multi-species and landings at multiple sites that difficult both monitoring and management. Therefore, notwithstanding its economic, social, environmental and cultural importance, it is recognized that there is a dearth of basic and high-quality information on SSF. Altogether, the inconsistency of the available data, high number of fishing boats involved and multiple gears used with various fishing techniques to target heterogeneously distributed resources, hampers the implementation of regular, broad coverage, efficient and cost-effective monitoring programs. Indeed, the lack of data on fishing fleet activities in both space and time is a major obstacle for long-term effective and responsive fisheries monitoring. To deal and overcome this problem, new information and communications technology (ICT) associated to the use of drones and gyrocopters are essential and can play a key-role in acquiring fishery-based data. In this context, this talk presents several case studies aiming to highlight how these technologies have been used to improve the monitoring and management of SSF in mainland Portugal

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Recreational abalone safety initiative implementing management and communication procedures to close a recreational fishing day due to predicted unsafe ocean conditions

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The Perth metropolitan Roe's Abalone resource is one of the only remaining sustainable abalone stocks on the door step of a capital city in the world and is therefore a unique recreational fishing experience for the Western Australian community. In 2018/19 approximately 18,000 people in the WA community were licenced to access this resource over an hour on four Saturday's in the summer months.

Fishers have been willing to risk their safety to obtain this highly valued catch. Since 2012, five recreational fishers have died and many more have required first aid and preventative actions to be undertaken by Surf Life Saving WA (SLSWA) volunteers. In 2017, this led to the need to change fisheries management arrangements to improve fisher safety. This was completed in consultation was SLSWA and Recfishwest, as the representative peak sector body.

One of these management changes was the implementation of a procedure to close a recreational abalone fishing day in the days prior based on predicted unsafe ocean conditions. This was used for the first time to close a recreational abalone fishing day on 12 January 2019.

This presentation will outline how the developed procedure went in a real-life scenario including communicating to 18,000 licence holders in the days prior to the closure, feedback received, lessons learnt and any future improvement, as well as the improved safety outcomes from implementing these changes.

27

A spanner in the works: lessons learnt from a review of the harvest control rules in the Queensland spanner crab fishery.

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commercial catch (TACC) has been managed using harvest control rules (HCR) since 1999. Rather than a data-intensive stock assessment approach to inform TACC setting, the HCRs in the spanner crab fishery has been based on the empirical assessment of two catch rate indicators. Following recent declines in the fishery indicators, the HCRs were revised for a fourth time with the intention of rebuilding stock biomass in order to meet policy objectives. We summarise the process of reviewing the rules using stakeholder engagement and management strategy evaluations. We also discuss lessons learnt (success and failure) from a fishery with a rich history of management under an empirical HCR framework.

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UCEs and reef fish trees: the utility of targeted capture techniques to illuminate the evolutionary history of fishes on coral reefs.

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1. James Cook University, Townsville, QLD, Australia

Targeted capture of ultraconserved loci across the nuclear genome is becoming a popular method for generating genomic scale data for phylogenetic reconstruction. While these methods have been used to reconstruction deep relationships across the fish tree of life only a handful of studies have begun to generate UCE data to reconstruction species level relationships of complete clades. For reef associated fishes, molecular studies in the last few decades have generated data from select mitochondrial and nuclear markers for about 44% of fishes found on coral reefs. However, data matrices tend to be incomplete in both species and gene overlap. As of yet, no 'classic' reef fish family is represented by a complete molecular species level phylogeny. Here, I highlight the progress of UCE generation in two iconic reef fish clades – butterflyfishes (Chaetodontidae) and parrotfishes (Scarini) with the aim of reconstructing complete species level phylogenies. In both cases, over 900 UCE loci are contained within 75% complete data matrices that represent 86% of all butterflyfish species, and 90% of parrotfish species. For butterflyfishes, the UCE phylogeny provided insight into the evolution of Red Sea endemics and the systematic placement of the genus *Roa* that has had little previous molecular sampling. For parrotfishes the UCE dataset highlights species level relationships that conflict with previous mitochondrial studies. Given the perils facing coral reef systems under climate change, the phylogenetic systematics of reef fishes is fundamental information required to identify species boundaries, geographic ranges and ultimate extinction risk. UCEs provide a powerful tool in the generation of phylogenomic datasets to complete the Tree of Life on coral reefs.

29

The evolution of traits and functions in herbivorous coral reef fishes through space and time

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Herbivory by fishes has been identified as a key ecological process shaping coral reefs through time. Although taxonomically limited, herbivorous reef fishes display a wide range of traits, which results in varied ecosystem functions on reefs around the world. Yet, we understand little about how these trait combinations and functions in ecosystems changed through time and across biogeographic realms. In this study, we used fossils and phylogenies in a functional ecological framework to reveal temporal changes in nominally herbivorous fish assemblages among oceanic basins in both trait space and lineage richness among functions. We show that the trait space occupied by extant herbivorous fishes in the Indo-Pacific resulted from an expansion of traits from the ancestral Tethyan assemblages. By contrast, trait space in the Atlantic is the result of lineage turnover, with relatively

recent colonization by lineages that arose in the east Tethys/Indo-Pacific. From an ecosystem function perspective, the Atlantic supports a depauperate fauna, with few extant herbivorous reef fish lineages performing each function. Indo-Pacific fishes support both more functions and more lineages within each function, with a marked Miocene to Pleistocene expansion. These disparities highlight the importance of history in explaining global variation in fish functional composition on coral reefs.

30

Evolutionary and ecological relationships of eyespots in coral reef fishes

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The eyespot, or ocellus, is a conspicuous marking found across a broad range of terrestrial and aquatic organisms. This eye-mimicking pattern has been shown to be effective in reducing predation by deflecting strikes away from non-vital organs or intimidating potential predators. The function of this marking has been studied extensively in terrestrial systems. However, the eyespot has been largely left unstudied in coral reef fishes; one of the most colourful and phylogenetically diverse groups of vertebrates on the planet. First, we map the distribution and reconstruct the origins of eyespots in coral reef fishes. This marking is very common on coral reefs. Of the 2663 reef fish species surveyed, 233 (8.7%) had eyespots. Eyespots have arisen independently many times, yet they are highly conserved after their origination within clades. Furthermore, this marking is concentrated at specific locations on the body. In relation to mimicking the eye, the eyespot often has an accentuated pupil; approximately 4 times larger than the real pupil. This is likely to draw attention away from the real eye. However, this feature is lost through development at sizes that strongly correlate with significant decreases in predation pressure. Our results suggest that there is an ontogenetic 'window' of effective function for eyespots, with most eyespot-bearing species losing this marking prior to adulthood. In coral reef fishes, eyespots may just protect the young and vulnerable.

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Most surgeonfish relatives don't live on coral reefs: Revision and relationships of the Acanthuriformes

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Acanthuroid fishes are often considered archetypal coral-reef fishes. Morphology of larvae and adults tells a different story, and redefines the Acanthuriformes to include the 4 traditional acanthuroid families (Acanthuridae, Luvaridae, Siganidae, Zanclidae) and 7 familes and 2 genera usually placed elsewhere. All share specialised tooth ontogeny. Based on larval morphology (particularly head spination, sculpting on the skull, early posterior development of pelvic fins) and absence of palatine teeth, Lobotidae is shown to include *Lobotes*, *Datnioides* and *Hapalogenys*, genera traditionally placed in separate families. Three-item analysis of 63 larval and adult characters shows Lobotidae is the sister group of the remaining acanthuriformes. Within the clade containing traditional acanthuroids are also Pomacanthidae, Drepaneidae, Chaetodontidae, Ephippidae and Scatophagidae. In addition, *Antigonia*, *Capros* and Leiognathidae are nested deeply within acanthuriforms on the basis of a number of osteological and larval characters. Traditional acanthuroids, Siganidae, Luvaridae, Zanclidae and Acanthuridae plus *Capros* are the most derived acanthuriform taxa. Recent gene-based phylogenies agree with some aspects of this revised Acanthuriformes, and do not differ significantly from the others. Of the 13 taxa of the redefined Acanthuriformes, only six (Acanthuridae, Zanclidae, Siganidae, Ephippidae, Chaetodontidae and Pomacanthidae) live predominately on coral reefs. Whereas, one (Luvaridae) is epipelagic, two (*Capros* and *Antigonia*) occupy outer shelf and slope habitats, and three (Leiognathidae, Scatophagidae, Drepaneidae) occupy inner shelf, mangrove and estuarine habitats. The three lobotid genera occupy freshwater and estuaries (*Datnioides*), low-relief shelf bottoms (*Hapalogenys*), and estuarine to pelagic environments, the latter in association with floating vegetation (*Lobotes*).

32

When is a Red Cod not a Red Cod? – A surprisingly involved detective story.

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Although not a targeted Australian species, the Red Cod is marketed in southern Australian states, taken as bycatch in demersal trawl fisheries on the continental shelf. Long treated as one of three species of the morid genus *Pseudophycis,* all of which were considered to be shared with New Zealand, recent studies have revealed that the Australian and New Zealand populations represent distinct and easily recognised species. Finding a name for what will become known as the Australian Rod Cod has been an interesting and convoluted process involving both genetic and morphological methodology.

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Ecology of reef based clupeiform affects genetic population structure

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Worldwide clupeiform fishes are a critical group in supporting higher trophic levels and commercial fisheries. Population scale studies of the genetics of this group have focused on temperate species and found low levels of variation between populations and stock units. In this study we present data from two sister species of reef based clupeiforms with differing spatial ecologies, *Spratelloides delicatulus* and *S. gracilis*. Sampling was performed in a nested design of latitudes along the Great Barrier Reef and multiple reefs within these latitudes. This study aimed to understand a relevant spatial scale for genetic differentiation of "sprat" stocks and to determine how the geomorphology of reefs interacted with the spatial ecology and genetic diversity of these fishes to influence patterns of connectivity. The two species have similar life history characteristics of demersal spawning and short age maxima but, differ in that *S. delicatulus* is most commonly found close to reefs and in lagoons, while *S. gracilis* is most common on reef slopes and surrounding waters. In general both species are more commonly found in close relation to coral reefs than in true pelagic waters. The genetic structure observed in these species stocks suggests that contrasting environmental preferences influenced paths of connectivity. We argue that reef fidelity, spawning behaviour and reef geomorphology play key roles in maintaining higher levels of genetic diversity at small spatial scales; this contrasts with the findings for temperate synonyms.

34

Restoring value in Indigenous Science: Beyond the MD SA Royal Commission

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Just as the Murray Darling River system has traced its path through the basin's landscape for millions of years, so too have these rivers been central to the cultural fabric, tradition, laws, economies and lives of its traditional owners for tens of thousands of years. The traditional knowledge of the Basin's Aboriginal peoples encompasses its geography, hydrology, biology, ecology and an intimate understanding of how management actions across the landscape impact the health and vitality of the rivers. Following decades of mismanagement, the MDB is suffering serious ecological decline. I argue that responses to this crisis will founder unless full recognition is given to Aboriginal rights and interests in the MDB and Aboriginal people are given a central decision making role in matters concerning the MDB. Just as the science of ecology is focussed on the interconnections between the elements of natural systems, Aboriginal science is a 'deep ecology' drawn from observation and understanding of the complex rhythms of a uniquely biodiverse and variable environment.

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Mapping stakeholder priorities in species and ecosystem threats in marine spatial planning

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People use and value marine environments in many different ways. Often particular marine species are central in the way many stakeholders interact with these environments. Through the process of participatory sketch-mapping, there are ways to identify hotspot locations that stakeholders' regularly use to access these priority species, known areas that support species persistence, and identify areas of ecological risks. Analysing this data using a mixed method of GIS fuzzy-set spatial modelling and qualitative analysis, can provide spatial insights into species priorities and their potential threats. This method provides a way to develop readily accessible outputs that can be used by both decision-makers and stakeholders to understand, discuss, and adapt marine spatial management approaches that support both social and ecological priorities.

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Monitoring Indigenous Sea Country: building a baseline for traditional and scientific partnerships in Australia

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The 'Old Way' practices of Australia's Indigenous Aboriginal and Torres Strait Islander peoples have sustainably managed the biodiversity and abundance of sea country resources for many thousands of years. In the Anthropocene however, marine environments are experiencing increasing cumulative pressures from many sources including coastal and industrial development, overfishing and climate change. The 'New Way' of modern marine science has developed technologies and methods to track and monitor the impacts of many of these threats to inform western management agencies. However, scientists usually lack the detailed place-based perspective which many Indigenous Australians have gained through a deep and long-term connection to country. Likewise, it is a challenge for Indigenous saltwater people to adapt their traditional ecological knowledge to understand the new pressures and effectively evaluate their own management systems. Clearly, the very different knowledge base of each group needs to be utilised to enhance our combined capacities to better manage Australia's marine environment. To this end, the Bardi-Jawi people of the southern Kimberley of northwest Australia and the Australian Institute of Marine Science are currently co-developing a sea country monitoring program. Here, we discuss the challenges, successes and learnings experienced so far in this exciting cross-cultural initiative.

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Building The Capacity And Performance Of Indigenous Fisheries Through Collaborative Partnerships.

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The starting point for the Indigenous Reference Group (IRG) was the development of the RD&E Framework for Indigenous fisheries (FRDC Project 2010/405).

This framework of eleven key R&D Principles and five national and community aspirations, is grounded in a vision to enable continuous improvement, rising from Primacy to Capacity Building.

This is the pathway to achieve sustainable increases in the capacity and performance of Indigenous fisheries, collectively and for individual communities. Indigenous communities will be the immediate and primary beneficiaries of this vision fulfilled.

Since its inception in 2010, the FRDC have supported the IRG's investment in a range of Aboriginal or Torres Strait Islander (ATSI) focused RD&E projects that aligns with the IRG's 5 strategic priority areas.

1. Primacy for Indigenous people.
2. Acknowledgement of Indigenous Cultural practices.
3. Self-determination of Indigenous rights to use and manage resource.
4. Economic development opportunities and rights for Indigenous people.
5. Capacity building opportunities for Indigenous people are enhanced.

The Indigenous fishery community is the core stakeholder identified in the quest to boost the capacity and performance of Indigenous fisheries.

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Filling the gap between the boat and fork – Connecting commercial fishers to the community

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The commercial Marine Scalefish Fishery (MSF) and Lakes and Coorong Fishery (LCF), similarly to other small community based fisheries across Australia and around the world, are facing significant challenges to build their economic, social and environmental credentials. These challenges are heightened as a result of the consumers' poor understanding and perception of small scale commercial fisheries' contribution to local and regional communities. This poor perception has amplified during the past decade through media and more evident recently when a licence holder expressed the following:

"*I walk into my local pub and I have to sit in the corner away from other people in my community and eat my dinner, as the job I have is frowned upon, I want to return to the good old days of feeling proud of being a commercial fisher and being part of a community*".

In other parts of the world, small-scale commercial fishers are investing in local and direct marketing strategies as a way to help commercial fishers resolve the challenges they face. In North America, local seafood movements such as the Walking Fish Cooperative and LocalCatch.org have been emerging with the aims of enhancing connections between commercial fishers and consumers. In particular, the Walking Fish initiative is a community supported fishery (CSF) concept offering the community the opportunity to 'subscribe' to a season of fresh and seasonally caught local fish. This allows commercial fishers to receive a better price for their catch, but more importantly reconnect them with their local and regional communities. These local and direct marketing strategies could provide an avenue for the MSF and LCF to build their economic, social and environmental credentials.

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Building a replacement species specific, spatially structured harvest strategy for the SA abalone fishery

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2. SARDI, Port Lincoln

3. Primary Industries and Regions SA, PIRSA, Adelaide, South Australia, Australia

Fishers in the valuable abalone fishery in South Australia hand-harvest Greenlip (*H. laevigata*) and Blacklip (*H. rubra*) Abalone. Combined total catches are approximately 670 tonnes and valued at about $25M. There have been three harvest strategies developed for the fishery: Zacharin (1997), Nobes et al. (2004), and PIRSA (2012). The most recent of these has been reviewed over the past three years, with that review nearing completion. The key steps in the review process have been (1) formulation of a harvest strategy working group comprising multiple stakeholders, (2) identification of deficiencies in the previous harvest strategy, and options for addressing these, (3) a review of alternate abalone harvest strategies, (4) an independent review of the efficacy and suitability of the available performance indicators, (5) development of a new harvest strategy framework, (6) rigorous testing of the 'settings', and (7) a consultative process, including a period of public consultation. This paper gives and overview of the process undertaken and provides an insight into the lessons learned during the review journey.

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Hooking into angler engagement in the NSW trout fishery: are our current science communication approaches effective?

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Anglers are increasingly becoming involved in the collection of information on the performance of recreational fisheries. While data is often required for management purposes and scientific assessment, the information is also valuable to anglers as it may lead to enhanced fishing experiences and understanding of management decisions. Despite increased angler cooperation and engagement in many monitoring programs (e.g., citizen science), the communication of results back to anglers is often poorly executed and uptake seldom evaluated. As such, this lack of effective feedback to stakeholders may be threatening the perceived value of their engagement in research and monitoring programs.

In NSW, trout anglers have a long history of involvement in stocking and management of the fishery through acclimatisation societies. However, many of these angling groups have reported a decline in the quality and opportunities for trout fishing in NSW. In order to evaluate stocking success and the status of NSW trout populations, long term monitoring programs have been developed for the fishery. The monitoring program includes a variety

of fishery dependant and independent techniques and increased utilisation of citizen science. Various approaches of angler engagement and science communication have also been trialled and utilised in this program. This paper discusses the process of stakeholder engagement, data collection and result dissemination for the NSW recreational trout fishery. The success of science communication approaches are evaluated and potential strategies to improve this in the future discussed.

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Closing the loop - Genuine adaptive management using existing data to develop meaningful objectives and the associated NSW Basin Plan fish response monitoring program.

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7. NSW Department of Industry, DPI Fisheries, Buronga, NSW, Australia

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Native fish populations in the Murray-Darling Basin (MDB) are in poor condition, with altered flow regimes being a major contributor to their decline. The implementation of the Murray-Darling Basin Plan provides the opportunity to improve flow regimes and contribute to the restoration of native fish populations. The Basin Plan, and associated state-based Water Resource and Long-term Water Plans, set specific ecological objectives and targets for native fish over five, 10 and 20 years. Associated Environmental Water Requirements (EWRs) to support life history characteristics have been developed to achieve the objectives and targets. These plans also include specific monitoring arrangements for native fish and other biota that will allow assessment and transparent reporting to the public and stakeholders, and enable improved decision making by water managers.

In this talk we will summarise how NSW DPI Fisheries and DOI Water have used existing data and knowledge on fish populations from historical monitoring programs such as the Sustainable Rivers Audit and the NSW Rivers Survey to guide the development of SMART objectives and targets for the Basin Plan. This is an example of genuine adaptive management by applying knowledge from previous investment to inform objectives and strategies that maximise evidence-based decision making. A summary of key results to date will also be provided.

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"Identifying gaps and opportunities: moving forward with the Murray Darling Basin Plan fish monitoring strategy"

Greg Ringwood[1], Stuart Little[1], Harry Balcombe[1], Wayne Robinson[1]

1. MDBA, Toowoomba, QLD, Australia

The Murray-Darling Basin Plan (BP) has a requirement to monitor, evaluate and report (MER) on the environmental outcomes and functions for native fish. The MDBA & CEWO are required to undertake MER at the Basin scale; and the Basin States are required to undertake MER at the Asset scale.

The BWS sets out the Quantified Expected Environmental Outcomes (QEOs) for the Key Fish Species (KFS) identified as expected to benefit from changes to flow regimes. The QEOs have been developed based on the BP environmental outcomes and ecosystem functions we expect to influence through its implementation. The BWS native fish QEOs provide a clear line of sight to the BP MER requirements.

The Basin Scale fish monitoring and evaluation strategy is being developed as a framework to evaluate the objectives and outcomes set out in the BP and by reference to the matters in Schedule 12, utilising the following BWS QEOs to assess the following high level outcomes:

- no loss of KFS currently present within the Basin;
- improved population structure of KFS through regular recruitment;
- increased movement of KFS;
- expanded distribution of KFS in the northern and southern Basin.

To develop the basin scale fish monitoring and evaluation strategy data made available to the MDBA has been analysed to identify how well the four high level outcomes are currently addressed at the basin scale and the power to detect change. The Strategy will identify where basin scale gaps currently exist and options to fill these gaps. The revised strategy will include the use of targeted monitoring, additional sampling methods and consideration of whether current fish sampling sites (e.g. MDBFS sites) are fit for purpose for BP MER.

The Strategy will guide BP MER parties, including the MDBA, to meet their Basin Plan MER responsibilities while collecting, analysing and reporting.

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2024 a fish and flow odyssey – what are the next steps in flow planning for fish in the Murray-Darling Basin

Stuart Little[1], Greg Ringwood[1]

1. Murray-Darling Basin Authority, Canberra City, ACT, Australia

The year is 2014. Following an exhaustive process, the MDBA published the Basin-wide Environmental Watering Strategy (BWS) to guide the planning of environmental watering over the longer-term at the Basin-wide scale. The published BWS captured the 2014 thinking about how environmental watering, and flows more generally, could be used to support native fish recovery.

Since that time, some key research projects (e.g. otolith microchemistry studies, the native fish population models) have increased our understanding of fish ecology enormously. There is also a broad suite of monitoring activities, both condition and intervention based, that have demonstrated the native fish outcomes from environmental water delivery and improved flow regimes.

With an increasing portfolio of environmental water entitlements in both regulated and un-regulated catchments, an increasingly complex array of management approaches are being used to maximise the effective use of water for the environment. The improved knowledge of fish and flow responses is being used for the coordination of water for the environment through planning groups like the Southern Connected Basin Environmental Watering Group.

This continuously improving understanding of what flows are required at the local, catchment and basin scale to promote fish movement and recruitment needs to be incorporated into planning documents, such as the next version of the BWS, to ensure we use the best available knowledge to inform our decision making.

We will discuss the upcoming opportunities that will influence the development of the next versions of the BWS. We will explain how we intend to leverage those opportunities; and how we will use the existing, and future, science and knowledge to inform environmental water planning for native fish in the Murray-Darling Basin up to 2024 and into the next phase of Basin Plan implementation.

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Impact of illegal recreational fishing on a fishery targeted species (Snapper: *Chrysophrys auratus*) within a remote no-take MPA

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1. NSW DPI, Taylors Beach, NSW, Australia

Quantifying illegal fishing effort within Marine Protected Areas (MPAs) is difficult and the impacts of illegal fishing on biodiversity are poorly understood. To provide an assessment of illegal fishing activity, a surveillance camera was deployed in a no-take area within the Port Stephens-Great Lakes Marine Park from April 2017-March 2018. To assess impacts of illegal fishing activity in the no-take area, Baited Remote Underwater Video Systems (BRUVs) were used to quantify abundance and size of snapper *Chrysophrys auratus* from 2011-2017. BRUVs were also deployed at two nearby fished locations and two other no-take areas to allow comparison. Over 12 months of camera surveillance, a total of 108 recreational vessels were observed illegally fishing within the no-take area (avg 9.0 ± 0.9 per month). The greatest number of vessels detected in a single month was 14 and the longest a vessel was observed fishing was ~ 6 hours. From 2011 – 2017, the abundance of *C. auratus* within the Seal Rocks no-take area significantly declined by 55%, whilst the abundance within the other fished areas and no-take areas did not significantly decline over the same period. Lengths of *C. auratus* in the Seal Rocks no-take area were significantly smaller in 2017 compared to 2013 which was driven by a decline in the number of legal sized fish over 30 cm. Based on mean number of illegal fishers per vessel recorded in the no-take area, and an allowable bag limit of 10 *C. auratus* per person, it is possible that more than 2,000 *C. auratus* are removed annually from this no-take area. There is a strong likelihood that illegal recreational fishing is causing a reduction on a fishery targeted species within a no-take MPA and measures need to be implemented to reduce the ongoing illegal fishing pressure.

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Effective fisheries management: Phasing out opera house nets to benefit yabby fishing and platypus in Victoria

Hui King Ho[1], Taylor Hunt[1], Anthony Forster[1], John Douglas[1]

1. Victorian Fisheries Authority, Melbourne, VICTORIA, Australia

This presentation reports on the Victorian Fisheries Authority's (VFA) work through the State Governments *Target One Million* Plan, to effectively phased out the use of opera house nets to maintain yabby fishing and protect air-breathing animals such as platypus, water rats and turtles.

Yabby fishing is an important, traditional and healthy pastime for recreational fishers, particularly families and children. However, the availability and affordability of opera house nets has resulted in them being used illegally in public waterways and impacting air-breathing wildlife. To help maintain the social licence of yabby fishing and protect vulnerable air-breathing species, the VFA worked with key stakeholder groups on a series of actions to phase out the use of opera house nets in Victoria;

1. Scientific research trials were conducted testing and identifying alternative wildlife friendly yabby traps with comparable and better catch rates for yabbies than opera house nets,
2. The VFA announced that new legislation would be introduced in 18 months' time (1st July 2019) to ban the use of opera house nets in Victoria providing lead time for recreational fishers and tackle stores to prepare for the change,
3. To raise awareness for the changes and to transition recreational fishers and tackle stores to using wildlife friendly yabby nets, a 'Yabby Net Swap' Program was conducted whereby fishers were able to swap up to three of their old opera house nets for free 'wildlife friendly' open top lift nets. Between December 2018 and February 2019, 20,000 wildlife friendly open top lift nets were distributed via 67 tackle stores throughout Victoria to recreational fishers.

The phase out of opera house nets in Victoria is an excellent example of effective fisheries management using strategic techniques to raise awareness of the issue, establish effective communication pathways and maintain recreational fishing social licence.

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Fishery reports cards for informing anglers about the status of popular recreational fish and fisheries

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1. Victorian Fisheries Authority, Queeenscliff, VIC, Australia

Fishery report cards provide a quick and concise means of presenting complex and detailed fishery data in a simplified format for anglers to digest. Fishery report cards are being used by the Victorian Fisheries Authority (VFA) to inform anglers about the status of important recreational species in the state.

Wild trout health cards have been produced for brown trout and rainbow trout since 2015. These utilise historic and contemporary electrofishing survey data to communicate and foster a better understanding of the past and current health of Victorian trout streams to anglers. Information on key population health indicators, such as changes in abundance and presence of multiple year classes, mature fish and recent recruits, is presented. Based on this information an overall health rating is provided for each stream. Health cards have been prepared for 21 streams, which are published in the annual *Talk Wild Trout Conference proceedings*.

Estuarine species report cards use angler-derived records from the Angler Diary Program, which has been in operation since 1997. Information on changes in catch rates and length frequency data for the previous five years are combined with angler knowledge (derived from a social survey of angler diarists) to describe trends and provide a fishery stock status rating. In 2016, reports were prepared for four species (black bream, estuary perch, dusky flathead and mulloway) and eight estuaries.

In a partnership between between the VFA, DELWP and the Recreational Fishing License Trust this approach has now been developed into an on-line report card resource for native fish, which commenced in 2017 (www.nativefishreportcard.org.au). Native Fish Report Cards summarise fish abundance and population size structure data obtained from annual electrofishing and fyke netting surveys into brief overviews of the health and status of important recreational (6) and non-recreational (4) native freshwater fish in 10 priority Victorian rivers.

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Using Decision Support tools to inform management and policy of climate related risks to fish productivity

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Warming ocean temperatures are considered to affect productivity of marine fished stocks, and institutions are straining to deal with this challenge. One approach to prepare institutions for projected impacts of climate change and facilitate adaptive management is to apply Decision Support Tools. Management Strategy Evaluation (MSE) is a form of Decision Support Tool that will be presented using a commercially important marine ectotherm as a case study. MSE is particularly useful for communicating and responding to environment-related risks and uncertainty in the management of fish stocks. It is important to identify the environmental mechanisms that drive population dynamics. Among marine ectotherms, reaction norms between body size, growth rate and temperature consists of faster growth rates but smaller adult body size as temperatures increase within the thermal tolerance of the species. Experiments have shown that reduced body size in warmer waters are due to the earlier onset of maturity. The size at onset of maturity decreased with increasing temperature, which in turn slowed down growth rate sufficiently to attenuate final adult size.

This presentation will use an MSE approach to estimate the benefits and risks of incorporating climate variables when making future projections on stock dynamics. The purpose is to provide management guidance when incorporating climate information into advice for management and policy makers

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Integrated approach to improving stock assessment of Black jewfish

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The Black jewfish (*Protonibea diacanthus*) is a large-bodied species of croaker that is highly prized for its table qualities. Black jewfish are aggregative in behaviour, making them a key focus of all stakeholders in the Northern Territory. They have been heavily overfished across their tropical Indo-West Pacific distribution with northern Australia from the western Gulf of Carpentaria to northern Western Australia remaining one of the last strongholds of this species. Despite a range regulatory controls, the species was listed as "Overfished" in the Northern Territory in the 2016 SAFS report (Saunders et al. 2016). Current stock assessment relies on outputs from a Stock Reduction Analysis (SRA). Increases in Black jewfish catches in 2017/18 after several poor years were inconsistent with the SRA forecasts, demonstrating a need for: 1) a better understanding of the drivers of fishery productivity; and 2) information on abundance and size structure. This FRDC-funded project is a collaboration between the Research Institute for the Environment and Livelihoods (Charles Darwin University), Australian Institute of Marine Science and the Northern Territory Department of Primary Industry and Resources, working with commercial fishers, Indigenous rangers and the recreational sector. Here we present preliminary outcomes from the beginning stages of an integrated project which aims to address critical knowledge gaps regarding the abundance and size-structure of Black jewfish populations and examine how the physiology of fish changes in response to environmental variability.

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Australasian Fishes might be your new online research tool

Mark A McGrouther[1]

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Whether your area of research is conservation, invasive species, fish monitoring, climate change, ecology or behaviour, the Australasian Fishes project could be of use to you. The project contains over 53,000 geotagged images of fishes from around Australia and New Zealand. More than 1600 people have submitted images of 2200 species, and the project is growing fast. Users can query the database by taxon, geographic place and other parameters to retrieve a grid of images or dots on a map. Data can be easily downloaded as a csv. You can query by place name, Lord Howe Island for example has 1106 records of 264 species, or use a polygon to define your own new area. You can also choose to receive notifications of new uploads from geographic areas or taxa of interest. Most observations are made by divers and snorkelers although there are many photos taken by anglers, spearos and beachcombers. Users regularly upload images of fishes they don't recognise. Here's where the community steps in to do the identification. In addition to the very enthusiastic and knowledgeable amateur fish enthusiasts, many ichthyologists from Australia, New Zealand and beyond are active members. Australasian Fishes has been online for 3 years and has documented more than 100 records of fishes found outside their recognised distributional ranges plus numerous observations that provide biological and behavioural information. It's easy to join at https://www.inaturalist.org/projects/australasian-fishes. I encourage you to do so.

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Preliminary Estimates of Seabird Bycatch in Australian Commonwealth Longline Tuna Fisheries, 2010-2017

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Incidental catch of non-target species (bycatch) occurs in most fisheries across the world. Estimating the total bycatch is a critical component of assessing the impact of fisheries on bycatch species and populations. However, obtaining reliable estimates of bycatch is often made difficult due to the often poor quality and quantity of reported bycatch data. Therefore, developing methods to provide robust estimates of bycatch using poor quality data sets is a priority for improved bycatch management. In this study, we apply two approaches to provide preliminary estimates of seabird interactions in Australian tuna longline fisheries between 2010 and 2017. This study was part of a global attempt to estimate the total seabird interactions in tuna longline fisheries operating in the southern hemisphere.

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Flow-mediated predator-prey dynamics influence fish populations in a tropical river

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Predator-prey interactions are an inherently local-scale phenomenon, but the intensity of these interactions can be mediated by abiotic conditions which can exert a multi-scaled influence through space and time. Understanding how multi-scale abiotic factors may influence local-scale biotic processes has proven challenging, however the hierarchical nature of riverine flow regimes makes these environments an ideal setting to test how predator-prey relationships may vary with multi-scaled flow variation. We developed a series of Bayesian hierarchical models to explore how predator-prey relationships between barramundi *Lates calcarifer* and their prey may be influenced by multi-scaled flow variables in the Daly River, northern Australia. We found that spatio-temporal variation in barramundi abundance was strongly related to both antecedent flow and the abundance of prey fishes (predictive $r^2 = 0.57$), and that barramundi abundance is more likely influenced by bottom-up, rather than top down predator-prey dynamics. We also found that the strength and direction of these relationships varied across the catchment and between seasons. We found stronger, positive relationships between barramundi abundance and prey abundance in the most downstream sites with higher mean annual flows, compared to upstream sites. These results indicate that the abundance of predatory fishes can be related to both recent abiotic (flow) conditions and the abundance of prey (biotic conditions), and provides strong support for the importance of bottom-up trophic dynamics. Management of iconic predators such as barramundi, should therefore consider both flow management and other key factors such as habitat maintenance to support their prey.

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Piscivory on coral reefs: An ecomorphological perspective

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Piscivory is a widespread ecosystem function, with up to 53% of fish species being piscivorous on a coral reef. To date, piscivory on coral reefs has primarily been studied with regards to what species piscivores feed on and how piscivory impacts the recruiting/juvenile fish pool. Unlike other ecosystem functions, piscivory is logistically difficult to study in situ due to its low frequency of occurrence. There is still therefore a lack of basic understanding on when, where, and how piscivory occurs. To better understand the nature of piscivory, we investigated the functional morphology

of piscivorous fishes and conducted performance-based experiments to link morphology to behaviour. We also investigated morphological traits such as teeth morphotypes, gape sizes, and body and fin shapes, to link broad ecological behaviours (habitat, activity) to distinct morphotypes. We found three distinct ecomorphotypes: benthic, nocturnal, and pelagic piscivores. Benthic diurnal and nocturnal piscivores display a wide array of gape sizes, potentially reflecting the large array of prey sizes and shapes in benthic habitats, highlighting the potential for niche partitioning based on maximum ingestible prey sizes. By comparison, gape sizes in pelagics are more restricted, suggesting limited variance in prey sizes, or restrictions associated with their feeding mode. We demonstrate how basic morphologies and performance-based experiments, may open broad new avenues for elucidating the nature, and thus ecological function of piscivory. Overall, we provide a broad quantitative framework for understanding the morphology and potential functions of piscivorous fishes on coral reefs, along with a better understanding of when, where, and how piscivory may occur on coral reefs.

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Trophic ecology of Great Hammerhead sharks (*Sphyrna mokarran*) on the east coast of Australia

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Publish consent withheld

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Predation risk influences the behaviour of mesopredatory reef fish over large spatial scales

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Predators exert strong ecological effects on their prey either directly via consumption or indirectly by inducing anti-predator behaviours. Evidence from manipulative experiments suggests that the perceived threat from reef sharks can alter the spatial use of mesopredatory reef fish, however, it is unclear whether such behaviours manifest over reef-wide scales. To assess this over larger spatial scales, we compared the amount of time spent in the water column by mesopredatory reef fish (lutjanids and serranids) recorded by baited remote underwater stereo-video systems in five minute segments before and after sharks appeared in the field of view. We found that mesopredatory reef fish spent less time in the water column, where they are vulnerable to predation, after the appearance of a shark. This effect was muted in a system where predators have been selectively removed (Scott Reef) compared to a system with intact predator populations (Rowley Shoals). The size of the shark also influenced the amount of time that *Lutjanus gibbus* spent in the water column, where the reduction in time spent in the water column was greatest in the presence of larger sharks. Furthermore, *Lutjanus bohar* spent longer periods of time in the water column at increasing levels of mean relief before the arrival of a shark, however the proportion of time spent in the water column decreased after a shark appeared and was consistent across all levels of mean relief. Collectively, our results provide evidence that the predation risk exerted by reef sharks alters the vertical use of mesopredatory reef fish over reef-wide scales. These behaviours are more complicated and nuanced than previously considered as they depend upon characteristics of both predators and prey as well as the environment in which these interactions occur.

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Trophic separation in planktivorous reef fishes: a new role for mucus?

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The feeding apparatus directly influences a species' trophic ecology. In fishes, our understanding of feeding modes is largely derived from studies of the rigid components (i.e. bones and teeth). Yet, a recently described lip innovation highlighted the role of soft anatomy in enabling specialized feeding modes. Similar diversification may also occur in the soft anatomy of the oral cavity. Using four key anatomical traits to classify 19 species (15 genera) of wrasses, we evaluated the relationship between morphological specialization of the oral cavity and diet. Our data revealed a previously undocumented anatomical adaptation in fairy wrasses (*Cirrhilabrus*) that underpins a novel feeding mode: the oral mucosa is packed with goblet cells, enabling them to secrete large quantities of mucus; a trait absent in other wrasses. This disparity reflects diet differences, with mucus secretion found only in planktivorous *Cirrhilabrus* that feed predominantly on amorphous organic material (potentially cnidarians). This suggests a cryptic mucus-based resource partitioning in planktivorous wrasses.

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Facilitation of macroalgal habitats across heterogenous substrates alters predation of epifauna by fish

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Habitat connectivity is an underlying process that determines the distribution of fish communities across and among seascapes. The fragmentation of macrophytes can reduce the connectivity for associated fishes and their invertebrate prey. Facilitation of macrophytes by basal habitat-forming species (i.e., sediment dwelling bivalves) can form facilitation cascades and extend the distribution of macrophytes across heterogeneous seascapes. The sediment dwelling bivalve, *Anadara trapezia,* provides small, isolated biogenic hard substrata for colonisation by the brown alga *Sirophysalis trinodis* into a novel habitat. While extending the realised niche of the alga, it also creates a fragmented habitat in contrast to contiguous patches on

neighbouring rocky shores. To better understand how altered abiotic and biotic conditions in the novel habitat influences the associated biodiversity of *S. trinodis* facilitated outside its natal habitat we contrasted the fish and invertebrate communities between natal and novel habitats. *S. trinodis* settled on *A. trapezia* were disconnected for fish communities and therefore created a refuge from predation for epifauna. Artificial habitat patches were created and placed at the same depth, alongside isolated artificial habitats to better understand whether altered abiotic conditions (i.e., sedimentation, depth, light availability) are the main driver of fish – invertebrate interactions. This work furthers our understanding community responses to habitat configuration in subtidal habitats and adds to the small but growing body of literature demonstrating the importance of positive interactions in structuring communities at the seascape level.

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In a fast changing world – what does good science look like?

Alistair Hobday[1]

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The pace of change in marine socio-ecological systems – human-linked endeavours that rely on natural resources for ecosystem services – continues to disrupt ocean life around the world. Impacts from climate change, marine pollution, and capture fisheries reflect the pressures of a growing population and a global economy. Projections of greater change will require dramatic responses to maintain ecological structure and function, and significant modification to existing governance and management approaches. Science will still have an important role to play in managing the oceans, but Good Science in a fast-changing world must also be Useful Science. We no longer enjoy the luxury of an equilibrium world, where restoration and recovery can return a system to a "natural state". Useful science must be produced faster, disseminated rapidly, and then converted into changes in human behaviour. Marine stakeholders will need to rely on best-available information, resulting in imperfect intervention and unintended consequences, alongside, hopefully, considerable success in minimising damage and maximising ocean health. We will need diverse real-time data collection and analysis supported by artificial intelligence, adaptive management and a willingness for fast-fail approaches, and strong partner networks built on trust and collaboration. This trust must be maintained in a highly connected world where failures go global and expertise can be questioned. As a marine research community, we must build skills and communication approaches to support our best efforts to maintain ocean health in the face of unprecedented change.

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The Rarest Fish in the World: Current Research on Desert Fish Management and Recovery

Scott A. Bonar[1]

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Fish species found in North American deserts represent some of the most unique, rare taxa in the world. Because these fishes live in aquatic "islands"- i.e., springs, streams and rivers separated from other water bodies by vast, harsh deserts- they have evolved to cope with life on the edge in their aquatic environments. Fish in arid lands are diverse, ranging from pupfish that inhabit small springs 40°C and almost five times the salinity of seawater; to some of the most southern trout species in North America; to the largest minnow in North America, a fish nearly 2 m long. A changing climate and increasing human population are putting these species at critical risk. Here I show how the habitat of these fishes is becoming increasingly fragmented and warmer; and discuss specific research being conducted to understand their tolerance to high temperatures and changes in habitat. Furthermore, I will show how research is providing managers tools to help cope with anthropogenic change such as techniques to cool streams, methods to captively propagate species to help prevent their extinction as drying waters become less habitable, methods to reduce interactions with nonnative species in the few water bodies remaining, and how the public is being acquainted with these animals. Protecting these genetic masterpieces from extinction in the face of anthropogenic change is a monumental challenge facing aquatic conservation biologists of North American desert regions.

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Malanda Gold: the tale of a unique rainbowfish from the Atherton Tablelands, now on the verge of extinction

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4. TropWATER, James Cook Uni, Townsville, Qld, Australia

5. Macquarie University, Sydney, NSW

Malanda Rainbowfish inhabits the small upper tributaries of the North Johnstone River, at elevations between 650–800 m. This small undescribed rainbowfish species was recognised as being a distinct species in the late 1990s, but detailed information on the species has been lacking. Longer terms studies going back to the late 1990s have demonstrated the species is declining in range due to invasion of Eastern Rainbowfish which hybridise and replace Malanda Rainbowfish populations. We have now completed extensive surveys of creeks in the upper North Johnstone River to define the current range of the species. In addition, detailed genetic work based on snps has clarified their distribution, taxonomy and phylogeny and ongoing introgression with Eastern Rainbowfish. Here we outline the results of the distributional surveys and genetic results and the conservation actions taken.

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From discovery to recovery: conservation of the Running River rainbowfish

Karl Moy[1]

1. University of New England, Armidale, New South Wales, Australia

In this talk I will present the full story of the conservation of the discovery and conservation of the Running River rainbowfish. It will include information on small-bodied fish translocations, the impact of predators, and movement data for the species.

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Spawning of a threatened upland galaxiid

Hugh Allan[1]

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Small-bodied freshwater fishes around the world are imperilled, with introduced species often reputed as one of the leading causes of decline in many small-bodied species. Many species are restricted to small, isolated refugia habitats and are protected from introduced species or threatening processes by in-stream barriers such as natural waterfalls. Where only a small number of populations remain, risk of losing entire species from stochastic climatic conditions, or from introduction of an introduced species is exacerbated. Establishment of additional populations through translocation is essential to ensure continuation of species and genetic diversity. Additional populations may also be founded by wild fish from existing populations or from hatchery-bred fish. Captive populations may also provide additional insurance against loss of fish in the wild. Understanding a species reproductive ecology is critical to the success of both captive and translocated populations. Newly established sites must meet ecological and environmental requirements of a species and be suitable for long-term occupancy. The study investigated aspects of the reproductive ecology of a newly-described threatened galaxiid. Findings relating to reproductive maturation, spawning time, fecundity, spawning habitat and growth rate of larvae and juvenile fish are essential for understanding and determining the suitability of translocation sites, and likely population dynamics following re-introduction.

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Size at onset of maturity (SOM) is a poor measure for setting Murray crayfish fishing regulations, size at functional reproduction (SFR) is the gold standard.

Charles Todd[1], **Scott Raymond**[1]

1. Arthur Rylah Institute, Department of Environment and Primary Industry, Heidelberg, VIC, Australia

Data collected from a Murray crayfish population that has been closed to recreational fishing for 6 years, identified that numerous females with no eggs (were non-berried) within the harvestable slot limit length (HSLL) of 100-120mm occipital carapace length (OCL). If this observation applies across the species then, the regulations set from previous SOM studies fail to protect most females from the possibility of being legally harvested through recreational fishing. We developed a SFR relationship from our data and show that the SFR_{50} is 106mm compared to SOM_{50} of approximately 92mm. Moreover, if our SFR results are applied to recreationally fished populations then only 25% of females would be in berry by the time they enter the HSLL, leaving a majority of non-berried females vulnerable to being harvested. We compared the SOM relationship with the SFR relationship in an age/size/sex stochastic population model. SOM substantially underestimates risk posed to a population from recreational fishing. Furthermore, our data disclosed a 2:1 sex ratio of females to males. Our model was only able to produce a 2:1 sex ratio in the catch data once we defined an uneven (2:1) encounter rate between the sexes. When applying this encounter rate in a recreational fishing scenario, the scenario exhibiting the highest level of risk is the current fishing regulations allowing take of non-berried females. Of all the scenarios using SFR, the scenario with least risk was no take of any female in the HSLL. SFR is an instantaneous measure of the likelihood of threat a recreationally fished population faces from fishing. It will instantly disclose the proportion of berried females at the lower end of the HSLL, identifying how vulnerable non-berried females are to removal and therefore impacting population persistence. We recommend that, at the very least, all females should be protected.

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Establishing refuge populations of threatened southern pygmy perch in north-eastern Victoria

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1. Department of Environment, Land, Water and Planning, Eltham, VICTORIA, Australia

Southern pygmy perch were once more widespread and abundant throughout the southern Murray-Darling Basin. However, threatening processes have contributed to their decline in abundance and distribution over the past 50 years. These declines have been driven by a variety of threats including; river regulation, riparian clearing, unrestricted stock access to waterways, water abstraction and alien species that continue to negatively impact remnant creek and wetland populations.

The current study employed species translocation as a strategy to establish new populations of southern pygmy perch across north-eastern Victoria. We outline the aims, objectives, actions and outcomes of a recent translocation using private farm dams to establish refuge populations. Southern pygmy perch were collected from four wild and one refuge population and translocated to four private farm dams in March 2018. The aim of the project was to establish refuge populations to; 1) reduce the species' risk of extinction, 2) for use as a source to establish additional populations and 3) to re-establish populations within their former range.

Here, we show that one-year-on the initial translocation of adult fish sourced from the wild have: 1) survived within two of the original four stocked farm dams, one-year following translocation, 2) successfully breed and recruited individuals into their respective farm dam populations, and 3) fish have been translocated from farm dams to two locations within Tabilk wetlands and an additional private farm dam/wetland at Mitchellstown. Research outcomes indicate that southern pygmy perch are amenable to farm dams/wetlands with suitable biotic and abiotic attributes required for the species to complete all stages in their life-history. The successful translocation, survival and recruitment of southern pygmy perch into selected

private dams provides water managers and conservationists with a strategy to protect similar threatened small-bodied native fish, using existing private and public resources.

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Learning from and adapting long term fish monitoring in the ACT

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1. ACT Government, Canberra, ACT, Australia

A number of challenges, including limitations in initial program design, and changes in management and resource priorities, can prevent the effective implementation and success of long-term monitoring programs. For the past 25 years, monitoring has been undertaken to track the relative abundance of fish in the Murrumbidgee River. In response to changes in resourcing, best practice methods and analysis, and ethical requirements, modifications to the methodology have been made throughout the life of the program. To assess how the program is tracking to meet its goals, and as part of an adaptive management approach, a review of the monitoring program was undertaken in 2019. This review includes consideration of long term trends, the impact of changes in methodology and the program's key achievements. Opportunities to improve the efficiency of the methods are noted and consideration is given to the importance of question-driven monitoring to improve our understanding of the ecosystem to directly inform management activities.

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Monitoring fish population responses to environmental water delivery in the murray-darling basin lessons and observations at the basin-scale five years in

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2. National Institute of Water and Atmospheric Research, Christchurch, New Zealand

3. Aquatic Ecology & Technology, Warrandyte South, Victoria, Australia

Environmental water is being delivered throughout the Murray-Darling Basin to achieve outcomes for native fish populations. The Long-Term Intervention Monitoring (LTIM) Program was established in 2014 to monitor the outcomes of environmental water delivery in the Murray-Darling Basin. Monitoring of fish populations is a core component of this program, with intensive surveys of population-structure, community-structure, and larval fish abundance carried out annually across seven areas within the Basin. While separate teams undertake the sampling in each region, standard methods were adopted to allow data to be combined into multi-site analyses of data from across all seven areas. Now five years into the program, it is timely to reflect on the lessons and observations to date, and to consider the extent to which the program is meeting its intended goals. Here we will present a snapshot of the multi-year datasets and associated analyses to date, discuss some of the challenges encountered in implementing the program, and reflect on the future direction of intervention monitoring and its role in meeting broader fish monitoring requirements in the Basin. Â

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Listening to the unseen horde: Parasites and environmental change in the Murray Darling Basin

Shokoofeh Shamsi[1]

1. Charles Sturt University, Wagga Wagga, NSW, Australia

Parasites are usually invisible, therefore, although it is estimated that over 75% of the earth biodiversity are parasitic species, their impacts on our ecosystems are frequently overlooked. This oversight is more pronounced when it comes to parasites in aquatic systems, due to significant shortage of experts in the country. This presentation starts with an overview of the importance of parasites in our environment. It then presents some of our research findings showing that there has been recent dramatic changes in populations of some parasites in the Murray Darling Basin which may be due to climate change and anthropological factors. The absence of these parasites may sound positive; however, it may indicate a serious decline or extinction of other microscopic non-parasitic species in the region too. A significant decline or extinction of a parasite may also create new ecosystem niches for other invasive parasitic species to exploit. Understanding the factors behind the absence of these species are highly informative for the sustainable management of our water systems.

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Understanding fish movement in the Murray–Darling: introducing the basin-scale acoustic telemetry array and database

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2. Murray-Darling Basin Authority, Science and Knowledge Division, Canberra, ACT

3. Arthur Rylah Institute, Department of Environment, Land Water and Planning, Heidelberg, Victoria

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5. Department of Environment and Science, Water Planning, Ecology, Science Division, Brisbane, Queensland

6. CSIRO Land and Water, Adelaide, SA, Australia

Management and conservation of riverine fishes requires an understanding of life history processes that influence population dynamics. As such, investigations of fish movement are now commonplace in aquatic ecosystems worldwide. Acoustic telemetry is a popular approach for understanding the spatial behaviour of fishes, but challenges exist, particularly for species that move over long distances. Acoustic receivers are a considerable expense, and thus, their spatial coverage is often limited, and critical behaviours may be missed for long ranging individuals that move outside

established arrays. These individuals may ultimately be detected on receiver arrays of unrelated projects, but without formal mechanisms, sharing of data is reliant on ad hoc communication among researchers and may not occur at all.

In 2018, to support monitoring and research projects on fish movement in the Murray-Darling Basin (MDB), the MDB Authority Joint Ventures program initiated the *Basin-scale Acoustic Telemetry Array* and associated database. The system provides a framework for collaboration and coordination of acoustic telemetry projects across the Basin, primarily via: 1) providing a 'backbone' receiver array for monitoring fish movement; 2) providing a mechanism to share detection data; and 3) forming a network of researchers involved in acoustic telemetry. Participation in the system provides researchers with access to detection data from 60 acoustic receivers deployed across ~5000 km of river in the northern and southern MDB, monitoring key river junctions and flow regulating structures. We present case studies from the MDB on the utility of the system, and ways it may support monitoring and research into the future.

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Temporal patterns in a lowland larval fish community

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Understanding mechanisms that underpin successful recruitment of fish populations are crucial to ongoing management of aquatic systems. At the base of this understanding is spawning and recruitment to larvae and early juveniles and key to management of environmental water, how flow relates to this process. This study monitored the larval fish community from October – December each year for five years in the lower Lachlan River, a heavily regulated lowland distributary river in central western New South Wales, Australia. Each year was vastly different hydrologically, with the second largest on record flood occurring in the third year of monitoring. The flood was the major driver behind change in the larval fish community, because it reduced the adult stock of Murray cod (through a blackwater event), and provided ideal conditions for carp, and then in subsequent years small bodied species (Australian smelt and flathead gudgeon), to reproduce. This study highlights the variable nature of these types of river systems, and how major hydrological events can shape recruitment patterns of freshwater fish. Furthermore, it sets a context for developing expectations around what can be achieved with environmental flows.

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Integrating acoustic telemetry with high resolution sonar to elucidate population-level effects of fish movement in a northern Australian stream

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Acoustic tracking can provide detailed insights into the movements of individual fish. Merging individual-level data allows us to build broad empirical understanding of the movement requirements of species and, thus, provides critical information for the effective management and conservation of fish populations. Nonetheless, it can be difficult to translate individual-level data into a comprehensive understanding of the importance of fish movement for processes that operate at population and species assemblage levels. For example, what is the effect of seasonal migration on the density of different species in a region and how might this affect food web dynamics, competitive interactions, etc? In this study, we integrate acoustic telemetry with high resolution sonar to address questions relating to the movements of fish in a seasonally flowing stream in Kakadu National Park in the Northern Territory, Australia. The stream runs through an operational uranium mining lease that will be decommissioned over the next few years. A key management concern is whether legacy mining effects may reduce connectivity between upstream reaches and productive downstream floodplains after the mine's closure. By integrating acoustic tracking and sonar imaging, we simultaneously track the movements of individual fish and changes in species abundance over the monsoonal wet season. Based on our results, we present a conceptual model of the assemblage-level outcomes of fish movement to support future decisions for rehabilitation of the mine site. We conclude that integration of acoustic and sonar technologies provides a powerful approach for addressing a range of questions relating to fish movement.

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Optimisation of monitoring methods used to characterise tropical freshwater fish community composition

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Fish monitoring programs designed to detect and assess potential impacts associated with mining in the Alligators Rivers Region (ARR), northern Australia, were developed and implemented by the Supervising Scientist Branch in the late 1980s. Fish community structure metrics from recessional-flow/early dry season sampling are used to detect potential long-term ecosystem level responses by comparing data gathered from downstream of mine sites to historical data and data from control streams unaffected by mining. Since the inception of these programs advances in technology and the decline of associated costs has allowed for innovation and implementation of new practices using underwater video cameras. Such innovations are necessary to improve worker safety through reduced contact with waters (e.g. crocodiles) and increase replication through efficiencies in data collection. Methodological changes require careful consideration so long term datasets are not compromised. To ensure comparisons can continue to be made with historical data, comparative quantification of different data collection methods is required. We present a side-by-side comparison of visual observation and videography methods used to characterise tropical freshwater fish community composition and the potential for using artificial intelligence to assist with species identification.

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Climatic forcing and larval dispersal capabilities shape the replenishment of fishes on a tropical coral reef

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Fluctuations in fish populations often relate to the supply of recruits by oceanic currents. Variation in these currents is typically driven by large-scale changes in climate, in particular ENSO (El Nino Southern Oscillation). The dependence on large-scale climatic changes may, however, be modified by early life history traits. Based on eight years of annual surveys, along 150 km of the Ningaloo (WA) coastline, we examined how ENSO influenced abundance of juvenile fish. We then investigated what traits make populations of some fish families more reliant on the ENSO relationship than others. Abundance of juvenile fish was generally positively correlated with the Southern Oscillation Index (SOI), higher densities recorded during La Niña years, when the ENSO-influenced Leeuwin Current is stronger and sea surface temperature higher. The relationship is typically positive and stronger among fish families with shorter pelagic larval durations and stronger swimming abilities. The relationship is also stronger at sites on the coral back reef, although the strongest of all relationships were among the lethrinids (r = .9), siganids (r = .9), and mullids (r = .8), which recruit to macroalgal meadows in the lagoon. ENSO also effects coral and macroalgal habitat and may moderate SOI–juvenile abundance relationship. Macroalgal canopies are higher during La Niña years, providing more favourable habitat for juvenile fish and strengthening the SOI effect on juvenile abundance. Conversely, loss of coral following a La Niña-related heat wave may have compromised post-settlement survival of coral dependent species, weakening the influence of SOI on their abundance. This assessment of ENSO effects on tropical fish and habitat-forming biota and how it is mediated by functional ecology improves our ability to predict and manage changes in the replenishment of marine populations.

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Coastal development can affect fish recruitment by altering mangrove-associated settlement cues

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Along coastlines worldwide, emergent and subtidal plant communities are threatened by human development, climate change, and pollution with subsequent effects on marine chemistry, and chemically mediated ecological processes, poorly understood. Waterborne chemicals, such as those derived from submerged or decaying vegetation can provide sensory information to aquatic animals, orienting them towards key resources or habitats. In the tropics, mangroves are a ubiquitous component of coastal ecosystems, associated with a wide range of habitats from river mouths to coral reefs. As mangrove litter fall often overlaps with periods of high larval recruitment, the chemical information contained in decaying mangrove leaves could provide a source of settlement cues for associated species such as fishes, drawing larvae towards shallow benthic habitats or inducing them to settle. In this study, juvenile Caribbean (Belize) and Indo-Pacific (Fiji) reef fishes both distinguished between chemical cues produced by leaves growing near, and away from, areas of substantial human development. When tested in Belize, leaf origin affected subsequent recruitment; settlement was highest on patch reefs paired with leaves from an undeveloped site and lowest to reefs paired leaves from a developed site. Chemical and microbial analysis of leaf tissue revealed significantly higher levels of toxic metals in leaves from the developed site, as well as significantly higher abundances of 50 bacterial OTUs from primarily anaerobic families. This evidence suggests that concentrations of assimilated pollutants or differences in leaf-associated microbial biofilms may account for the variable behavioral responses observed.

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The influence of onshore winds on estuarine fisheries production

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Fisheries production is highly variable and is increasingly being linked to oceanographic variables. Recruitment of larvae to suitable habitats is a key bottleneck for many species with the vast majority of spawned larvae often failing to settle in suitable habitat. Over 100 years ago, Dannevig (1907) showed that onshore winds correlated with estuarine fisheries catch 4 years later. Since then, the importance of onshore winds has rarely been considered as a driver of fisheries productivity. This study tests this hypothesis by using 10 years of catch per unit effort (CPUE) for 4 species in 8 NSW estuaries and the onshore winds calculated from a global wind model. We show positive correlations between onshore winds during the spawning periods of species and the CPUE for most species-estuary combinations. Onshore winds may be a significant contributor to larval settlement in estuaries, either as a direct transport mechanism or potentially as a driver of upwelling which creates more favourable larval conditions along the coast. This study suggests that onshore wind should be considered as a driver of estuarine fish productivity in future studies.

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Early warnings: monitoring replenishment of the western Victorian snapper stock

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Managing fisheries for sustainability involves managing a dynamic equilibrium between the numbers of fish being removed by fishing (and dying naturally), and the numbers of new fish entering the population (i.e. juvenile recruitment or 'replenishment'). This is challenging because replenishment of fish populations is generally highly variable and unpredictable, and, except for highly depleted situations, is often independent of variation in spawning biomass.

Traditional fisheries stock assessments rely largely on 'fishery dependent' sampling programs where information on replenishment rates is not obtained until the fish have recruited to the fishing gear. This means that management of fishing pressure 'now' and in the immediate future, is unaware of how many new fish are being produced. Failure to reduce fishing pressure and build resilience into the spawning biomass in the face of prolonged poor recruitment is no doubt behind many fishery declines. Fishery dependent surveys targeting the early life-stages can provide early warnings to trigger management actions before it's too late.

This presentation describes a 'fishery independent' survey that provides an annual index of 0+ age snapper recruitment for the highly important "western Victorian stock", that extends from central Victoria to south-east South Australia. The survey has been operating for 27 years. The long-term data show that, even at high spawning biomass, replenishment can fail catastrophically, and repeatedly, and clearly indicate the vulnerability of this fishery to uncertain replenishment. Importantly, the survey data successfully predict trends in catch rates from recreational creel surveys and provide managers and stakeholders with a simple statistical forecasting of biomass and fishery dynamics with a 6-year lead time. The presentation will conclude with some discussion of the secrets to the success of the program and how the predictive capability could be used to inform management of the predominantly recreational fishery.

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The South Australian Snapper fishery – a complicated tale of different stocks

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The Snapper (*Chrysophrys auratus*) is a highly significant fishery resource throughout the coastal sub-tropical and temperate regions of Australia. It supports important commercial and recreational fisheries in each of the five mainland states and as such has attracted much research effort and fishery management focus over many years. Through the early to mid-2000s, South Australia consistently made the dominant contribution to the national commercial catch of Snapper. Nevertheless, for the past decade there have been significant management concerns that have resulted in numerous management interventions. One complication has been the different trends in fishery productivity of the two major stocks. The commercial catches from the stock based in Spencer Gulf (SG) have declined since 2007 with particularly low levels recorded between 2012 and 2018. As such, this stock is now classified as 'depleted'. Over the same period, catches from Gulf St. Vincent (GSV) increased exponentially to a record level in 2010 and remained high until 2015 before also declining between 2016 and 2018. These very different trends in fishery statistics for the two stocks relate to different demographic processes, particularly recruitment rates. The population dynamics of Snapper are fundamentally driven by inter-annual variation in recruitment of the 0+ year class. SG has experienced unprecedented poor recruitment throughout the 2000s. In contrast, between 2000 and 2010, GSV was the beneficiary of the recruitment of several strong year classes. Such different temporal patterns in recruitment have driven the different trends in fishable biomass and fishery productivity of the two stocks. The rebuilding of biomass, particularly in SG, depends on the production of a strong recruitment year class. This requires that there remains enough adult biomass to produce sufficient eggs for recruitment to occur when the environmental conditions are right for the maximum survivorship of the eggs and larvae.

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Discriminating natal source populations of a temperate marine fish species using larval otolith chemistry

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For many marine fish species, spawning grounds and nursery areas are spatially segregated and larval dispersal is an obligate process that links life history stages. However, empirically quantifying connectivity between natal source populations and nursery areas remains a significant challenge. Such connectivity determines whether a fish population is essentially a self-recruiting stock, or if it forms part of a larger meta-population where recruits originate from multiple sources. Previous research has struggled to differentiate between such stock structure models for King George whiting (*Sillaginodes punctatus*; Perciformes) in southern Australia, largely due to difficulties in identifying source populations of larvae. In this study, larvae were collected from plankton tows throughout the recognised spawning area in South Australia in 2017 and 2018. We analysed the elemental composition of 21-56 µm diameter otoliths from 3.1-5.0 mm larvae (5-18 d) using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), to determine whether larvae were sourced from a common origin, or if multiple spawning grounds contributed to recruitment. Multi-elemental (Li, Mg, Mn, Sr, Ba) otolith signatures differed significantly between regions, primarily related to differences in Li and Ba. Although elemental signatures were year-specific, larvae were allocated to their region of capture with 56-72% accuracy. Larvae in each region hatched at the same time yet had different otolith chemistry, providing strong evidence that those from the two regions originated from spatially-segregated spawning grounds. As such, our findings support the hypothesis that the South Australian stock conforms to a meta-population structure of multiple self-recruiting populations. This study has demonstrated the usefulness of otolith chemistry to discriminate natal source populations of planktonic larvae, which provides a basis to quantify connectivity during dispersal.

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Analysing population structure and connectivity through otolith chemistry of stout whiting, sillago robusta

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Otoliths provide information on fish movement, habitat use, as well as surrounding environmental conditions. Bio-mineralisation causes trace elements to accrete onto these hard parts, with accretion rates dependant on a range of biological and environmental factors. The objective of my study was to determine population structure and potential connectivity among stout whiting (*Sillago robusta*) populations along the coast of New South Wales. First, I determined (i) age-growth relationships of fish, followed by (ii) examining variation in otolith chemistry among fish from different fishery zones and finally I (iii) investigated variation in life histories of fish from two populations using otolith chemistry. The study was completed by ageing otoliths and discriminating adults from juveniles, followed by analysis of the concentration of minor and trace elements (Li, Mg, Mn, Cu, Zn, Sr, Ba and Pb) within otoliths. Analyses consisted of core and edge readings of all samples and transects (core to edge) of selected adults to construct otolith profiles. Age-growth relationships showed higher abundances of small juveniles originating from southern and northern populations, with older/larger adults found in the central fishery zones. Using only adult samples (>3 yrs), there were differences between core and edge signatures and among populations, while multivariate analyses showed higher variability among edge signatures compared to core readings. Otolith profiles showed unique chemical signatures within and among populations. Findings show the possibility of juvenile habitats located further inshore from the northern and southern sampled populations, with individuals undergoing both depth and latitudinal stratification. Otolith chemistry showed an altered accretion rate during juvenile life compared to adult life, as well as heterogeneity and potentially connectivity among populations. The results indicate a larger meta-population, which may require management and conservation strategy revision in order to assure the protection of spawning/nursery sites present within the eastern Australian stock.

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The bold and the sperm: positive association between boldness and sperm number in the guppy

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Assessing the consequences of personality traits on reproductive success is one of the most important challenges in personality studies, and critical to understand the evolutionary implications of behavioural variability among animals. Personality traits are typically associated with mating acquisition in males, and hence linked to variation in their reproductive success. However, in most species sexual selection continues after mating, and sperm traits (such as sperm number and quality) become very important in determining post-mating competitive success. Here, we investigate whether variation in personality traits is associated to variation in sperm traits using the guppy (*Poecilia reticulata*), a species with high level of sperm competition. We found a positive association between boldness and sperm number but not sperm velocity, suggesting that bolder males have increased post-copulatory success than shyer individuals. No association was found between exploration and sperm traits. Our work highlights the importance of considering post-copulatory traits when investigating fitness consequences of personality traits, especially in species with high level of female multiple matings and hence sperm competition.

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Diethylstilbestrol (DES) mediated paradoxical masculinisation does not impair reproduction in the pest fish *Gambusia holbrooki*

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Hormonal sex reversal of fish has been a useful tool to study sex and reproductive system and to produce single sex stocks for various applications such as aquaculture. However, paradoxical effects have been reported in several fish species but information on the extent of effects in terms of viability and reproduction of such individuals are lacking. This work therefore examined the effects of paradoxically masculinised *Gambusia holbrooki* produced following oral administration of a feminizing hormone Diethylstilbestrol (DES) infused feed at concentration as low as 20 mg DES/kg feed to newly parturated fish for 30 days. The masculinized fish were raised for further 90 days without hormone, and then bred to assess male reproductive ability and progeny quality. Expression profiles of select genes—anti Mullerian hormone (*amh*), ovarian (*cyp19a1a*) and brain aromatase (*cyp19a1b*)—important for testicular and ovarian functions respectively were examined using quantitative PCR. Survival rate of masculinised fish after 90 days of rearing was not significantly different (t-test, p=0.11) to controls, indicative of the individuals to live healthily. Interestingly, breeding (pairwise mating) assessment showed the males did perform similar to untreated males, in terms of progeny clutch size (p=0.23) and survival of parturated progeny reared for 10 days (p=0.25). Together the results show paradoxically sex-reversed males are fully functional. This is reflected in the comparable activity of *amh*, *cyp19a1a* and *cy19a1b* between the reversed males and untreated males (p=0.34). Paradoxical masculinisation in *G. holbrooki* is unexpected given that DES has been used relatively effectively without paradoxical effect in many fish species. The outcome of producing viable paradoxically sex-reversed males with full testicular functions is novel and may shed more light on plasticity of sex differentiation in viviparous fish specifically from the view point of reproductive endocrinology and ecological applications.

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Should females mate with old males? Effects of male age and sexual experience on sperm quality, mating success and offspring fitness

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An aging male presents a female with an interesting mate-choice dilemma. Survival to old age could be indicative of 'good genes' that would benefit her offspring; and an older male is more likely to have mating and parental care experience that might provide a female with direct benefits that increase her own reproductive output. However, aging might lower the quality of a male's sperm, which could negatively impact her fecundity and decrease offspring fitness (older fathers sire young with shorter lifespans); and aging could also reduce the direct benefits provided (older males have a greater likelihood of having acquired an STD). So, is mating with an older male advantageous or not? And, crucially, what is the effect of male age itself, as distinct from any conflated effects that arise from increased mating experience? Using mosquitofish (*Gambusia holbrooki*) as our model system, we disentangled the individual effects of aging and lifetime mating effort on: sperm traits, male mating success, and cross-generational effects on offspring fitness. Male mosquitofish were housed either with access to females with whom they could mate (experienced), or with visual but no physical access to females (naïve). At three points in each male's lifetime (young, middle-aged and old) we tested the quality and quantity of their sperm. At 16 weeks post-maturity we ran behavioural assays to determine the cumulative effect of sexual experience on male mate choice, mating performance and immuno-competence. Finally, we conducted a series of controlled matings to measure the reproductive quality of the offspring produced by experienced and naïve old males. Our results highlight intriguing interactions between male age and mating history meaning that, for females, the answer to the mate-choice dilemma seems to rest on what a male has been up to previously, rather than his age *per se*.

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Prey fish use a chemical alarm signal to communicate risk and coordinate defenses against predators

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Despite our inability to perceive it, fish communicate and interact with one another constantly in their natural ecosystems. Fish have an extremely acute sense of smell, yet, apart from mating pheromones and chemicals released during intrasexual competition, few chemical signals have been identified. In part, this may be due to a lack of testing to determine if chemicals are passively-released cues or constitute recipient-directed signals. One potential signal used by many different fishes are chemical disturbance cues released during a predator chase. Disturbance cues alert nearby conspecifics of risk, evoking a fright response involving rapid movements (dashing) and reduced activity. Here, we aimed to test whether disturbance cues in fathead minnows (*Pimephales promelas*) are in fact alarm signals used to warn conspecifics of risk, rather than passive cues. We manipulated the audience present nearby minnows (either no audience, an unfamiliar audience, or a familiar audience) during a simulated predator chase and obtained disturbance cues. We then measured each cue's potency through a behavioural bioassay of independent receivers' responses to each cue. If disturbance cues function as a recipient-directed alarm signal, we expected more disturbance cue production when fish were in groups with familiar individuals rather than unfamiliar or isolated individuals. Indeed, receivers responded to disturbance cues produced by groups of minnows and not isolated individuals through tighter shoaling. Shoaling has previously been associated with enhanced survival of prey during predator encounters. Additionally, receivers reacted most strongly to disturbance cues from familiar minnow groups by reducing overall activity, increasing dashing, and greatly increasing shoaling, demonstrating the importance of audience composition for signal production. Our results suggest that minnow disturbance cues are likely a socially-directed alarm signal used to communicate risk and coordinate group defenses among familiar conspecifics and highlight the need for further investigations of chemical signals in fishes.

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Sex-specific responses to intraspecific competition in the mosquitofish *Gambusia holbrooki*

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Intraspecific competition constitutes an important source of selection that can influence the development, expression and evolution of many phenotypic traits. Although often neglected in studies of intraspecific competition, the sex of competitors can alter the nature and intensity of competition between individuals, and in turn can influence the development of resource-dependent traits. We examine how the sex of focal and competitor individuals affect developmental responses to competition in the Eastern mosquitofish *Gambusia holbrooki*. We raised individuals of both sexes either alone or in the presence of a male or female competitor, and measured their juvenile growth rate, time to maturity and size at maturity; for males we also measured their gonopodium length, sperm quantity, and sperm velocity. We found that plastic phenotypic responses to competition were dependent on the sex of the focal individual, the sex of their competitor and sometimes an interaction between the two. When there was a competitor present, regardless of its sex, males had slower growth rates and took longer to mature, but eventually matured at the same size. Like males, females also showed slower growth rates in the presence of a competitor, but in contrast to males, reached maturity sooner and at a smaller size than when there was no competitor present. Presence of a competitor influenced male sexual traits and there was little evidence that these effects were mediated by the sex of the competitor. Males that were reared with competitors had longer gonopodia for their body size, as well as fewer and faster sperm. Overall our results suggest that the effects of competition on resource dependent traits are different for males and females potentially due to sex differences in adult life history strategies.

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A fish can change its stripes: behavioural drivers of rapid colour change in bluelined goatfish

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The capacity for fish to rapidly change their colour is well documented, however, the behavioural drivers of this are less understood. We know that fish use colour change for camouflage, but it is possible that it also plays a key role in communication. Bluelined goatfish (*Upeneichthys lineatus*) have the capacity to change their colouration and body pattern from white to a striped red and white pattern in seconds, often when foraging. Despite several anecdotal reports of this behaviour, colour change in this species has not been previously studied. Goatfish often drive multispecies associations and it is possible that goatfish use colour change to collaborate for increased food acquisition via a 'safety in numbers' approach. It is feasible that colour change may be not only an intraspecific signal to conspecifics but a signal to other species as well. This project assesses the process of rapid colour change by bluelined goatfish as a communication tool. Using a novel approach to examining colour change we deployed 3D model goatfish in different colour morphs to determine whether the colour red is being used as a signal or if it is the pattern, regardless of colour, that fish are responding to. This study allowed us to remotely obtain information on the communities and behaviours of other fish in response to these different colours, without the influence of human observers. It is likely that teleost fish use rapid colour change as a signalling tool, and understanding the capacity in which this occurs is important in further understanding the significance and evolution of this behaviour.

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Cleaner fish as vectors of parasitic diseases

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In marine environments, cleaner organisms (i.e., fish and shrimp) are considered as key to ecosystem functioning. Cleaners remove ectoparasites from the skin of other organisms (clients), which provide food for the cleaners. Recently, cleaner fishes have been applied in aquaculture as mechanisms to reduce ectoparasite infection. This revealed that cleaner fishes are not only susceptible to parasitic diseases, but can also have a role in disease transmission between cultivated fish. Despite a large body of work on cleaning interactions on coral reefs, the potential role of cleaner fishes in disease transmission between clients in the wild remains unexplored. This study aims to evaluate if the bluestreak cleaner wrasse *Labroides dimidiatus*: a) naturally carries parasites in the wild; b) is susceptible to generalist parasites under laboratory condition and; c) transmits parasites to other fishes through cleaning interaction. To answer these questions, we have combined comprehensive ectoparasite and endoparasite surveys of wild *Labroides dimidiatus* from the Great Barrier Reef using dissections and detailed laboratory experiments. The experiments performed were divided in two sets. First, we exposed *L. dimidiatus* to three groups of generalist ectoparasites: gnathiid isopods (*Gnathia aureamaculosa*), monogenean flatworms (*Neobenedenia girellae*) and ciliate protozoans (*Cryptocaryon irritans*), quantifying parasite prevalence and infection rates. Second, we tested if the above generalist ectoparasites are transmitted to *L. dimidiatus* via cleaning interactions with infected clients (the sea goldie *Pseudanthias squamipinnis*, a common client in the wild). Understanding if cleaning behaviour can mediate parasite transmission on reef fishes is a critical component of cleaning interactions that has not been considered previously. The results will, among other consequences, inform the possibility of employing *L. dimidiatus* as biocontrols in tropical aquaculture.

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Should we try, try again when it comes to fish habitat rehabilitation?

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Rehabilitation of the Tharwa section of the Murrumbidgee River in the ACT, a severely sand-affected river reach, has been attempted on three occasions with mixed results. If a first attempt at rehabilitation does not prove to be successful, is it worthwhile to attempt rehabilitation again? A substantial rehabilitation project was undertaken across ~ 1.5 km of the river length from 1998- 2001, which had limited success because most habitat structures were either smothered by sand or the channel migrated away from the structures. Despite the outcomes of the initial intervention another attempt at channel and habitat improvement took place in 2013, this time with much larger structures over a smaller river length (~ 100m). The second project was successful, both in terms of improving channel morphology and native fish presence. Based on the successful outcomes from the second rehabilitation attempt, funding was obtained for a third project that took place in 2018. What was learnt from this project progression, and is it true that if at first you don't succeed, you try again? This presentation will examine the different approaches used for this project and the recommendations about rehabilitation projects that have been gained through its progression.

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Shark conservation hindered by lack of habitat protection

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The world's shark populations are in decline, with conservation management efforts hampered by lack of knowledge of their habitat requirements and the geographic distribution of their preferred habitats. Here, we used shark occurrence records collected by commercial fisheries to determine habitat suitability, the location of suitable habitat for sharks within the Australian continental Exclusive Economic Zone (EEZ), and quantify the amount of suitable habitat within existing marine protected areas (MPAs). We developed generalised linear binomial models using proportional occurrences of sharks as a response variable for Lamnidae (mackerel), Alopiidae (thresher), and Carcharhinidae (requiem) sharks. Additionally, since taxonomic division of species does not always reflect habitat preferences, we aggregated species from the Lamnidae and Carcharhinidae families ('*combined* sharks' in the models). Using a set of environmental predictors known to affect shark occurrence including sedimentary, bathymetric and biological variables, we found that models including temperature and turbidity were ranked highest in terms of their ability to predict shark distributions, with high potential for these sharks to be impacted by climate change. We used these results to identify geographic regions where habitat was most suitable for pelagic sharks within the Australian EEZ. Our results revealed varying family-specific patterns, with suitable habitat particularly under-represented in no-take zones within MPAs and located in areas exposed to fishing pressure, potentially increasing the vulnerability of these pelagic shark species.

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Behavioural assessment of Murray cod decision-making and implications for conservation and welfare

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One key aspect of fish behaviour which has implications for welfare and conservation is understanding how fish make decisions when faced with complex, dangerous and uncertain environments. Behavioural research indicates that other animals experience affective states which serve to generate appropriate responses when presented with complex situations; in the human literature these affective states are referred to as "emotions". The aim of this study was to determine if Murray cods' responses to ambiguous/uncertain stimuli are influenced by affective state. Using a typical go/no-go judgement bias test, Murray cod were trained to enter a compartment at one corner of a large tank to receive a positive outcome (food), and to receive a negative outcome (chased by a net) after entering a compartment at another corner of the tank. Six Murray cod approached the positive outcome compartment significantly faster than the negative outcome compartment, indicating that they successfully learnt the discrimination task. Decision-making was then examined by opening three compartments in intermediate locations between the negative and positive outcome locations. In unrewarded probe tests, fish showed a typical generalisation curve indicating that they were combining knowledge of the positive and negative outcomes to decide whether to approach or avoid these intermediate compartments. Preliminary findings suggest that following 24 hours of housing with a larger Murray cod, which was predicted to induce a negative affective state, fish showed a slower response to the intermediate compartments compared to control-housed fish. The findings presented here confirm the remarkable learning ability of fish, and are consistent with the involvement of affective states in complex decision-making in Murray cod. The possibility that fish experience affective states has important implications for welfare and we discuss how knowledge of decision-making processes can help us predict how fish will respond and adapt to natural and anthropogenic environmental challenges.

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In the red: the first national IUCN Red List assessment for Australian freshwater fish

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Since the first formal list of Australian threatened freshwater fish in 1980, the number of listed Australian freshwater fish has grown rapidly. Similarly, the number of lists themselves has grown with statutory and non-statutory State, national and international lists in existence. The current national statutory list (EPBC) contains 38 freshwater fish, while the ASFB Threatened Fishes Committee (TFC) list contains 63 threatened freshwater fish. The IUCN Red List is internationally recognised and has been the primary information source for global conservation status since the 1990s, but for threatened Australian freshwater fish was incomplete, out of date and consequently largely ignored. A national assessment of the conservation status of Australian freshwater fish was long overdue and as the IUCN, ASFB TFC, and the EPBC lists now all use identical assessment criteria, it was timely to do a national Red List assessment of Australia's threatened freshwater fish.

A 5-day workshop was held in February 2019 with 3 IUCN facilitators and ~37 'experts' attending from all states/territories. Prior to the workshop experts were allocated taxa to review and spatial datasets were compiled and screened for obvious errors and mapped. A total of 241 taxa were assessed and reviewed and distribution maps for all taxa were refined to accompany the published assessments. 37% of taxa were assessed as threatened (1 extinct, 31 critically endangered, 42 endangered, 16 vulnerable) with another 16 taxa assessed as near threatened; 2 as data deficient and 133 as least concern. It is expected the Australian assessments will be published on the IUCN Red List in December 2019. This species proposed for listing on the Red List are discussed, and the threats across all species summarised. The Red List assessment provides a baseline for a future national EPBC review of the status of freshwater fish.

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Using social media to inform conservation risks and guide management actions for the endangered Mary River Cod

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The recovery of threatened fish species requires reliable up-to-date information on trends in status, threats and effectiveness of conservation actions. Often resources to gather this information are limited, necessitating the exploration of novel approaches to inform recovery efforts. Mary River Cod (*Maccullochella mariensis*) are an iconic freshwater species listed as endangered, in part due to their restricted distribution, loss of habitat and angling pressures. Initial surveys estimated fewer than 700 breeding adults remained, confined to less than 30% of their former range. In response a recovery plan was implemented to address risks and assist recovery. The emergence of smart phone technology and social media apps provide unique and potentially valuable tools for informing conservation efforts. This research explores the utility of social media posts on *M. mariensis* captures to gauge threat levels, trends and inform the refinement of management actions and legislation aimed at recovering populations.

Data gathered from posts included capture dates, localities, mortality events, keywords highlighting deficiencies in current regulations, and basic biological information. Results from over 350 Mary River Cod social media posts reveal an increasing trend in angling pressure, with a rapid rise in the past 4 years. Reported catch rates are higher in spring and summer, and mortality events are more common between January and March. Where location information was reported, or identifiable by photographic features, most captures occurred in the Mary River catchment where cod are protected, and in some cases within legislated closed waters. To be effective, fisheries management requires legislative controls that reduce key threatening processes and assure high public compliance rates. This study highlights social media data can be used to inform trends and guide improvements to management actions that will aid species recovery by more effectively targeting threatening processes.

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A quantitative assessment of the biodiversity of rocky reef fish assemblages and a range of anthropogenic threats across the Hawkesbury Shelf Marine Bioregion

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There has been substantial debate over the importance of various suggested threats to environmental, social and economic values of the Hawkesbury Shelf Marine Bioregion (HSMB). Several threats, and threatening activities, have been listed in the HSMB Threat and Risk Assessment, however, the confidence levels for these risk ratings was generally limited or inferred. Hence, quantitative assessments are required to determine which are the major risks and their relative importance. This project will involve the detailed assessment of fish assemblages (an environmental value/asset) along the coast of the HSMB in order to assess their biological condition (using a control charts approach) and provide a quantitative assessment of a range of proposed threats (e.g. pollution, storm water run-off, point source discharges, shipping, recreational fishing, commercial fishing etc). Intermediate rocky reefs (20-40m) have been targeted as an initial habitat to assess fish assemblages due to the high value of this habitat to a range of stakeholders and the threats that they face. These fish assemblages will be sampled using stereo baited remote underwater video and remotely operated vehicles. Variation in the diversity, abundances and sizes of the fishes on these rocky reefs will be modelled against a range of quantified or estimated threat levels across the bioregion to quantify their apparent importance levels. This research is currently being undertaken and the results of these analyses and modelling will be presented.

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Modelling the spatial distribution of rocky reef fish assemblages in the Hawkesbury Shelf Marine Bioregion

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The spatial distribution of demersal fish assemblages is strongly influenced by geographic gradients of latitude, depth and habitat types. In New South Wales, rocky reef fishes have been monitored by NSW Fisheries using stereo baited remote underwater video stations (stereo-BRUVS) in the Tweed-Moreton, Manning and Batemans Shelf Bioregions, representing a latitudinal gradient of ~750 kilometres. Using these data we build a model to assess the relative importance of habitat type, depth and structural complexity on the spatial distribution of rocky reef fish assemblages. Applying the most parsimonious model, we predict the expected abundance and diversity of rocky reef fishes in the Hawkesbury Shelf Marine Bioregion (HSMB), which encompasses Australia's most densely populated coastline. To assess predictive performance, we validate the model using an independent stereo-BRUVS data set collected in the HSMB as part of the Hawkesbury Shelf Marine Bioregion Biodiversity project. Using this approach, we assess how the rocky reef fish assemblage in the HSMB compares to other bioregions in New South Wales.

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Movement and distribution of Greynurse sharks (*Carcharias taurus*) in an ocean warming hotspot

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Population demography is largely underpinned by the movements of a given species. Understanding how movement in marine species is influenced by environmental factors such as ocean temperature is key to predicting how species use their environment and how they will respond to perturbations. Whilst temperature is thought prompt migration in some shark species, few studies have investigated whether fluctuations in temperature correlate directly with changes to localised movement. Understanding such relationships are particularly important in ocean warming hotspots such as the East Australian Current. Greynurse sharks (*Carcharias taurus*) are a large, migratory species known to aggregate in rocky gutters and caves. Whilst the migratory habits of *C. taurus* have been studied previously, it is unknown how changes to ocean temperature affect migration and localised movement of this species. This project investigates effects of changing ocean temperature on *C. taurus* movement in waters on the east coast of Australia. To assess the impact of temperature on localised movement, active tracks of acoustically tagged *C. taurus* at Fish Rock, NSW, are examined and compared to temperature data logged by the tags. Migration patterns of individuals of this population over a 11 year period are compared to bottom water temperature data along the same spatial and temporal axes. We anticipate that range and movement patterns of *C. taurus* have not changed significantly over this time period despite increases in sea surface temperature over this time. We predict that seasonal temperature will correlate with shark migration and that short, more localised movement will remain unaffected. Understanding such movement patterns of *C. taurus* will help identify essential habitat for the species in a changing environment and inform conservation policy and management.

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Is it time to consider replacing divers and snorkelers with Remotely Operated Vehicles (ROVs)?

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Publish consent withheld

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Acoustic recording technology as a method for monitoring the use of Australian Marine Parks by recreational vessels

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The large size and remote nature of Australian Marine Parks (AMPs) makes monitoring the degree of vessel activity within them challenging, especially for non-commercial vessels without on-board tracking systems. The primary aim of this study was to use archival acoustic recording technology (SoundTraps) for understanding patterns of use of AMPs by small vessels.

Between July and August 2018, one acoustic recorder was deployed to the Cod Grounds MP and two to the Solitary Islands MP off the New South Wales coast. These locations were selected because illegal fishing is considered to be a significant threat in both of these AMPs. The instruments recorded between 32 and 35 days of continuous acoustic data. The data was reviewed using spectrograms to identify hourly vessel presence as well as discrete vessel presence and duration. Vessels recorded were assigned behavioural categories in order to thoroughly assess vessel activity within and around the marine parks. Vessel presence was also analysed for diel, weekly, and environmental patterns in order to determine conditions that may increase the presence of vessels near the AMPs.

Data collected during this project demonstrates how acoustic monitoring technology has the potential to significantly improve our understanding of AMP usage by small vessels. The continuous data collected by the SoundTraps could not be collected using traditional monitoring methods such as patrols, and already we have a better understanding of how vessel activity changes with time of day and day of the week. This work will form part of a cost effective, repeatable data collection methodology that, in conjunction with other monitoring tools, will inform compliance risk management and planning for AMPs.

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Spatial ecology of coral reef fish functions in a transitioning world

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Coral reefs around the world are experiencing dynamic shifts in ecological conditions. In order to understand, and shape, what future reefs may look like, it is crucial for coral reef conservation to identify the main drivers of ecosystem stability. Herbivorous fishes play a crucial role in buffering disturbances to coral reefs and hence support reef resilience, by removing algal biomass from reefs. To date, research has amassed critical information on the 'who', the 'how' and the 'what' of fishes removing algae from reefs. In the light of recent ecological challenges, however, new approaches are required, which explicitly consider the dynamics of shifting ecosystems across space and time and the 'where' and ' when' of functional delivery. In particular, assessments of spatial and temporal heterogeneity and connectivity of ecosystem function require more detailed exploration. While we seem to have growing knowledge on the status quo of what fishes do and where they move, new approaches are needed to explicitly consider the spatial range of fish feeding *behavior*, not the mere *presence* of fishes, and need to investigate levels of spatial and temporal connectivity between fish communities. Insights from such approaches will allow a better understanding of how the ecosystem function of algal removal may shift alongside degrading habitats and what we can do to shape the future of reefs.

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Patterns and drivers of movement for a coastal benthopelagic fish, *Pseudocaranx georgianus*, on Australia's southeast coast

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Knowledge of connectivity and population structure is integral to the sustainable management of fished populations, yet such information is unavailable for many species over scales relevant to their exploitation. We examined broad-scale patterns and drivers of adult movement for a putatively mobile carangid (*Pseudocaranx georgianus*) on Australia's southeast coast using an angler tag-recapture dataset. More than 6300 individuals were tagged and released across 1007 km of coastline, with anglers recapturing 157 (2.48%) individuals during a 14-year period. Median distance moved was 5 km and a substantial proportion of individuals (19%) were recaptured at their release location. Recapture latitude was also strongly predicted by release latitude ($r^2 = 0.87$). However, a broad range of movements were observed (0–508 km), with 6% of individuals moving further than 100 km. Most individuals recaptured in areas now designated as Marine Protected Areas (MPAs) were originally released in the same

area (79.2%). Larger body size, longer periods at liberty, and releases during Spring all positively influenced distance moved. Results are consistent with a model of restricted movement over an intermediate scale, punctuated by occasional large movements. Our findings suggest adult movement of *P. georgianus* in southeastern Australia primarily occurs over smaller distances than the current spatial scale of management.

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Novel use of passive satellite archival telemetry in sawsharks: insights into the movement of the common sawshark *Pristiophorus cirratus* (Pristiophoridae)

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Movement patterns of a species is vital for conservation and management strategies. This information is often difficult to obtain in the marine realm for species that regularly occur at depth or in cryptic environments. The common sawshark (*Pristiophorus cirratus*) is an elasmobranch species for which no information is known regarding its movement ecology. Despite this lack of data, these animals are still regularly landed in large numbers as nontargeted catch in the southeastern Australian trawl fisheries. To investigate the movement ecology of this species, three common sawsharks were tagged with passive satellite archival tags (PSATs) off the coast of Tasmania, Australia, in 2016. Tags were successfully retained for up to three weeks, but movement results differed on an individual basis. Archived data displayed diel vertical movements in one individual. One individual displayed a minimum horizontal movement of approximately 70 km in 21 days. The data presented here provide insights into the ability of sawsharks to regularly move both horizontally and vertically in the water column which was an unexpected result for this small benthic species. This information suggests these sharks are not regionally resident but capable of making substantial movements. These data provide the first account of movement ecology on the family of sawsharks: Pristiophoridae. Furthermore, this combination of substantial horizontal and vertical movements is critical information for fisheries managers dispelling the previous idea of a sedentary life history which could have significant implications for local removal of individuals on populations around southeastern Australia.

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Fine scale behaviour of bluespotted flathead around a designed artificial reef

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Designed Artificial Reefs (ARs) are deployed with the goal of increasing habitat complexity, therefore allowing more fish to inhabit an area, benefitting local fishing. Since ARs are usually subject to high fishing pressure, the regional flow on effects of an AR are subject to a delicate relationship between a fish's benefit from the reef, and potential overharvest, thus it is crucial to quantify how species interact with ARs. This study used a VEMCO Positioning System (VPS) to monitor the movements of 48 Bluespotted flathead around a designed AR, which consists of 36 concrete modules deployed in two cross patterns. The flathead were surgically tagged with acoustic transmitters, 22 of which contained accelerometers. The VPS allowed fine scale monitoring of flathead movements, offering an insight into how flathead interact and feed around the reef. In addition to this, a published production model was modified to estimate the AR's direct contribution to flathead growth-production. Flathead tagged at the AR may spend ~9% of a year (40 days) at the reef which could support 1.84 kg of flathead growth-production annually. The AR's flathead assemblage comprises adult fish, so growth rates are low, but the AR becomes an important component of the flathead's feeding habitat, with the AR's rich supply of zooplanktivorous baitfish. This is the first study to examine the fine scale behaviour of flathead within and around an AR, and highlights the delicate balance between growth-production, movements and increased fishing pressure around ARs.

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Using acoustic tracking to improve marine reserve design: movement patterns and habitat connectivity of juvenile Luderick (*Girella tricuspidata)*

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Quantifying the movement and habitat use of fish across the seascape is essential for understanding connectivity and evaluating the design of conservation strategies, such as marine reserves. Many species of reef fish use seagrass meadows as nursery areas and migrate to reefs as adults. Few studies, however, have tracked the movement of juvenile reef fish and it is unknown if seagrass nurseries supply individuals to reefs nearby or far away. Gaining a better understanding of these movements can help guide the size and placement of marine reserves to protect fish populations through ontogeny by limiting their exposure to fisheries capture and conserving habitats. Luderick (*Girella tricuspidata*) are an important herbivorous reef fish that supports commercial and recreational fisheries, making them a target species for management. Here, we use acoustic telemetry to track the movement of juvenile Luderick within a seagrass (*Posidonia australis*) habitat and their movements to rocky reefs in Jervis Bay Marine Park, NSW. Juvenile Luderick showed strong site fidelity to seagrass habitat and performed migrations to adjacent rocky reefs. One individual, however, performed a home range shift to a reef five kilometres from the capture site. These findings indicate that no-take reserves may be an effective tool in conserving Luderick populations and highlights the importance of incorporating connectivity between nursery and adult habitats into reserve design.

101

Investigating social interaction dynamics in reef manta rays

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Social interactions are a key part of the overall environment an animal experiences. In reef manta rays (*Mobula alfredi*), habitat use is thought to be strongly influenced by preferred social relationships, resulting in the partitioning of populations into social units with fission-fusion properties. Though social and collective behaviours are often governed by simple interaction rules, their dynamics are rarely understood quantitatively, and it is therefore difficult to answer questions on their function and evolutionary significance. Here we describe several methods (underwater focal follows, use of underwater mirror, aerial video of whole groups) to quantitatively analyse social dynamics in manta rays, and present preliminary results. We investigate social interactions at cleaning stations, and during feeding and reproductive events, asking whether reef manta rays modify their cephalic lobe and whole-body movements according to social situation, or in response to seeing their own reflection. Results will be valuable in understanding ecological processes that operate at short timescales, such as information transfer and cooperation, and are relevant to conservation of this threatened species.

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Does ocean warming affect quantity discrimination ability in sharks?

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Ocean warming can induce physiological and behavioural effects in marine predators that can cascade through ecosystems. A lack of understanding of the effects of elevated temperature on shark behaviour remains an impediment to forecasting ecosystem-wide impacts. Port Jackson shark eggs were incubated and reared at current and projected end-of-century temperatures (+3ºC). We tested juvenile's learning ability with a quantity discrimination task. The mortality rate of sharks reared in warm water was 41.7% compared with no mortality in the present-day sharks. Contrary to expectations, our results suggest that surviving hatchlings from the elevated-temperature group took fewer days to reach learning criterion and had a higher proportion of correct choice over all trials compared to hatchlings reared under present conditions. Additionally, this is the first data suggesting that sharks can discriminate different quantities. Our results indicate that learning and behaviour might may play a role in allowing elasmobranchs to overcome some of the deleterious effects of global warming, but further research is needed to fully comprehend these findings.

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Now entering the Twilight Zone

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Worldwide there is limited sampling of deep marine environments (> 50 m) due to increased costs and logistics. Australia's deepwater environments are unique and underexplored habitats. From tropical to temperate seas, these ecosystems are heterogeneous areas of rapidly changing environmental gradients that we have not been able to fully appreciate. In deeper areas of the Great Barrier Reef we found diverse fish assemblages, but more importantly these fish assemblages are very different to shallow water fish assemblages. We investigated the components of habitat that explained the variation in fish assemblages and found species distributions were dependent on specific habitat features. Both the physical components – the substratum, reef architecture and structural complexity – and the biological components – such as encrusting organisms – were important. These specific habitat associations may limit the spatial extent of deepwater fish populations. We are underestimating the diversity of deep marine ecosystems, as the rates of discovery in the Twilight Zone are still increasing. New species discoveries, depth extensions and large geographic range extensions highlight how much more we do not know about deeper ecosystems. Thus, while some species appear to be widespread in distribution, we may be overestimating and perhaps overconfident of these deeper fishery resources.

104

Planetary Boundaries and the Sustainable Development Goals on a Blue Planet

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Global sustainability frameworks such as the Planetary Boundaries and the Sustainable Development Goals (SDGs) have become central to society's desire to build a healthy future for ourselves and our planet. And yet, despite the spatial dominance of marine ecosystems, the increasing pressures on the world's oceans, and the critical role marine systems play in supporting human wellbeing, particularly in developing nations, the oceans are not achieving a central role in these initiatives. This lack of emphasis crosses research, and prioritisation and funding by decision-makers. In this presentation, I will discuss the outcomes of this lack of emphasis on the oceans. I will show (i) how improved integration of marine systems influences our understanding of the risk of crossing planetary boundaries, and (ii) how limited progress towards SDG 14 (Life Below Water) is likely to affect long-term attainment of social and economic SDGs, particularly for countries highly dependent on fisheries and tourism or for those developing a blue economy. As the United Nations Decade of Ocean Science for Sustainable Development approaches in 2021, we need to ensure marine systems are playing a central role in earth system governance.

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Dissecting the Menindee fish deaths

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The Darling River in Western NSW, its tributaries and floodplains, are important for the breeding and recruitment of numerous species of native freshwater fish. The Menindee Lakes have provide important recruitment habitat for numerous species, including Golden Perch with subsequent dispersal throughout the northern and southern Murray-Darling Basin, while the Lower Darling River supports one of the most robust Murray Cod populations in the Basin.

In the summer of 2018/19, widespread fish death events occurred across several river systems of the Murray-Darling Basin, the most devastating of which was in the Lower Darling River adjacent to the Menindee Lakes. A series of three events between 15 December 2018 and 28 January 2019 saw millions of fish perish along an approximately 40 km reach of the river, including threatened, iconic and recreationally revered species such as Murray Cod, Golden Perch and Silver Perch.

Whilst fish death events have previously been recorded in the Lower Darling and other systems across the Murray-Darling Basin, their size and relatively rapid succession of the three events made them unprecedented. The fish deaths received national and international attention, and have been the focus of numerous agency and independent assessments. Here we will explore the conditions leading up to the events, suspected causes of the fish deaths, and the response actions undertaken by government and communities to support recovery of the local native fish populations.

1. DPI NSW Fisheries (January 2019). Fish Death Interim Investigation Report. Lower Darling River Fish Death Event, Menindee 2018/19.

106

Findings of the independent panel assessment of the 2018-19 fish deaths in the lower Darling

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4. Charles Sturt University, Albury-Wodonga

5. Griffith University, Nathan

6. Latrobe University, Wodonga

Three large-scale fish death events occurred in the Darling River near Menindee between December 2018 and January 2019. In January 2019, the Minister for Agriculture and Water Resources (the Minister) wrote to the Prime Minister requesting an independent panel be established to assess the fish deaths of 2018-19 in the lower Darling to identify causes, evaluate management responses and provide recommendations. In this talk I will cover the panel's findings in regards to the water management, events, and conditions leading up to the 2018-19 fish deaths to identify likely causes and some of the key recommendations from the report to reduce the risk of future fish kill events.

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The people of the river: What the Darling River fish deaths mean to the Barkindji

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Barkindji means "people of the river", and for more than 40,000 years the Barka (the Darling River) from Bourke to Wentworth has been the "centre of existence" for the Barkindji people. In 2015, the largest native title claim in NSW acknowledged the Barkindji people to be the traditional owners of a large portion far western New South Wales (from the Murray River to near the Queensland border), including much of the Darling River downstream of Bourke.

Badger Bates is a Barkindji elder, community leader and renowned artist who grew up in a tin hut on the bank of the Barka. He says when the river is healthy, everything flows – Barkindji people are happy. The river supports their well-being by providing food, resources and medicine, and it also reinforces connections to country and culture.

When the river is sick the Barkindji people are sick, physically and socially. Crime rates, family violence and mental health issues rise when the Barka doesn't flow. For decades the Barkindji people have held serious concerns regarding water management in the Barka and its catchments. In the summer of 2018/19, the deaths of millions of fish near Menindee highlighted their concerns, bringing the health of the river system to national and international attention.

Like aboriginal communities across the Murray-Darling Basin, the Barkindji feel a responsibility to care for their river, and hence they want to be better engaged in water management and Basin Planning discussions. They hope the disastrous Menindee fish deaths drive change in water management and policy at the state and federal level, and they want to be a part of recovery processes moving forward. They strive for a shared commitment to care for their lifeblood, their river.

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Cod or canaries: Are the Menindee fish deaths forewarning the demise of a river and the communities that depend on it?

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In the summer of 2018/19 millions of fish perished along a 40 km reach of the Lower Darling River near Menindee in Western NSW, including the iconic and recreationally important Murray Cod, Golden Perch and the threatened Silver Perch.

For the local community, the Menindee fish kills were heart-breaking and will have an enduring impact on tourism, local business and social amenity of the town and region. Millions of dead fish lined the river banks from December 2018 to February 2019, and the threat of further fish kills persisted even longer given as the long dry continued.

The local community were central to the immediate actions undertaken in response to the fish death events, relaying critical information from the field, spending hours trying to help struggling fish survive, assisting with monitoring and research activities, and helping to coordinate on ground efforts aimed at reducing further fish deaths.

With the spotlight on Menindee and the Lower Darling River, the community worked hard to influence economic and social recovery by securing funding and government support for a range of local projects. But the community also want meaningful change when the spotlight leaves town. They want fish to survive, birds to breed, tourists to visit, and local business and families to prosper. Put simply, they want their river to flow and for there to be life after death.

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Death by Numbers: Learning from the Menindee fish deaths to inform future management

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Understanding how the Lower-Darling fish deaths affected the fish population is critical to formulating an effective recovery plan and establishing a baseline condition against which to monitor recovery. To this end, NSW DPI Fisheries undertook a number of assessments during, immediately after and some months after the death events. Assisted by local recreational anglers, dead Golden perch, Murray cod and Silver perch were collected and their otoliths analysed to investigate the age of some of the largest fish affected. In the days following the third death event, a rapid appraisal of fish numbers in the Menindee Weir pool was conducted using a non-invasive, boat-mounted, sonar survey. Finally, a more comprehensive standardised fish community survey of the Lower-Darling River was conducted in June 2019, comparing sites affected by the fish death events with sites unaffected by the fish deaths. Insights gained from all these activities included: Murray cod killed during the events were much younger than had been reported in the media; there were reasonable numbers of fish still remaining immediately after the fish death events; and importantly, the species abundance, diversity, size composition and health of the fish community in the Lower Darling appears to be impacted by the death events. It is important that the fish community continue to be monitored over the upcoming years to track the effectiveness of recovery plans.

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Creating oxygen refuges for fish during hypoxia-caused fish death events – evaluation of emergency measures

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During the recent hypoxia-driven fish death events in the lower Darling River, community and the NSW Government responded with the emergency deployment of a number of bubble aerators around Menindee. Furthermore, many other technologies were suggested to the government for short-term re-oxygenation and creation of oxygen refuges to reduce the risk of ongoing deaths. These included the **addition of chemicals**, such as granulated calcium peroxide and sodium percarbonate; **direct air injection** using macro, micro and nano bubbles or venturi pumps; **mechanical aeration** using water paddles, water jets and flow over structures; and **destratification** using down currents and bubble plumes. Here we provide a preliminary review of these technologies, with emphasis given to their efficacy, practicality and potential to cause additional water quality issues and environmental harm. Additionally, data collected from field and laboratory trials of bubble aerators, a venturi pump and a micro bubble aerator during the recent death events will be presented. We provide a short list of the most promising techniques that warrant further feasibility assessment with respect to their cost-effectiveness, scalability and practicality.

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Linking water quality and river flow to fish health to improve our predictive capacity around fish kill events.

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Following three significant fish kill events in the Darling River near Menindee between December 2018 and January 2019, an independent assessment recommended the need for better modelling approaches to predict rivers that may be more susceptible to fish kill events. We present such a GIS-based model that uses various data sets, including cyanobacteria biomass, river flow and temperature that can help identify river systems where

additional stresses on fish health may pose a greater risk of a fish kill event. The creation of this predictive model can provide water managers better decision support tools that may improve water management options across the Basin and ultimately reduce the frequency of fish kill events.

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Lessons learnt from reef fish functional ecology

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Ecosystem function is the movement or storage of energy or material. On coral reefs, fishes play a leading role in an array of critical ecosystem functions, and as such, are important conduits of function. This has led to a dizzying array of 'functional' studies on reef fishes, and a growing uptake of functional evaluations in monitoring and management. Yet while the term 'function' is widely used, ecosystem functions themselves are rarely quantified directly, leading to shortcomings in our understanding and the application of functional concepts. In this talk I will explore our understanding of reef fish functional ecology by drawing on the results of some of our recent studies that have surprised us. From assessing the ubiquity of the well-known triggerfish-urchin functional linkage, to patterns of macroalgae grazing on the Great Barrier Reef versus the Caribbean, when we look at functions in detail our assumptions can be overturned. From these results I will highlight the importance of: a) considering the context of the system in question when examining function, and b) thorough functional evaluations in furthering our understanding of reef fish functional ecology on coral reefs.

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Pelagic subsidies underpin fish productivity on a degraded coral reef

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Coral reefs harbour high productivity in nutrient-poor tropical oceans. This exceptional productivity can be explained by high recycling rates, deep-water nutrient enrichment, and assimilation of external production. Fishes consume this productivity through multiple trophic pathways and, as a result, dominate consumer biomass. Their reliance on pelagic vs. benthic productivity pathways has been quantified from the tissues of individual fish, but the contribution of different energetic pathways to the total productivity of coral reef fish assemblages remains unquantified. Here, we combined high-resolution surveys and individual biomass production estimates to generate the first energetic map of a full coral reef fish assemblage, from the smallest to the largest fishes. We found that the windward section of a coral reef on the Great Barrier Reef delivered an average fish productivity of 4.7 kg $ha^{-1}day^{-1}$, of which 41% was derived from water column photosynthesis, 29% by the epibenthic reef surface, 14% from cryptobenthic microhabitats and 11% from adjacent sandy areas. The critical energetic contribution of pelagic subsidies would remain undetected if considering fish standing biomass alone, since the high productivity of reef planktivores originated from a relatively small biomass. Pelagic subsidies increased toward forereef zones and were strong drivers of total fish productivity. Furthermore, contrary to internal fish production, pelagic subsidies were positively associated to tropographic complexity. Importantly, this study took place on a reef with only ~6% of coral cover following multiple coral mortality events. Thus, our study offers hope that reefs subject to coral loss can still maintain considerable fish productivity underpinned by pelagic subsidies provided that they retain topographic complexity.

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Stable isotopes infer the value of Australia's coastal vegetated ecosystems from fisheries

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Wild capture fisheries provide substantial input to the global economy through employment and revenue. The coastal zone is especially productive, accounting for just 7% of the total area of the ocean, but supporting an estimated 50% of the world's fisheries. Vegetated coastal ecosystems – seagrass meadows, tidal marshes, and mangrove forests – are widely cited as providing nutritional input that underpin coastal fisheries production; however, quantitative evidence of this relationship is scarce. Using Australia as a case study, we synthesised fisheries stable isotope data to estimate nutritional input derived from coastal vegetated ecosystems, and combined these 'proportional contribution' estimates with total annual catch data from commercial fisheries to determine species-specific dollar values for coastal vegetated ecosystems. Based on data from 96 commercially important fish species across Australian states (total landings 14 x 10^6 tonnes pa), we estimate that Australia's coastal vegetated ecosystems contribute 78 million AUD y^{-1} to the fisheries economy. Two thirds of this contribution came from tidal marshes and seagrasses that were both equally valued at 31.5 million AUD y^{-1} (39.4%) followed by mangroves at 14.9 million AUD y^{-1} (18.6%). The highest dollar values of coastal ecosystems originated from Eastern king prawn and Giant mud crab. This study demonstrates the substantial economic value supported by Australia's coastal vegetated ecosystems through commercial fisheries harvest. These estimates create further impetus to conserve and restore coastal wetlands and maintain their support of coastal fisheries into the future.

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Stable isotopes indicate significant saltmarsh provisioning for two commercially important penaeid species in a temperate seagrass dominated estuary

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Estuaries, and the habitats therein, are highly important nurseries for a range of commercially exploited species. Despite the widely recognised importance of estuarine habitats they remain some of the most threatened systems in the world. Anthropogenic impacts such as land clearing,

increased urban run-off and the modification of tidal regimes is known to lead to significant habitat loss and fragmentation. Such habitat loss, and subsequent loss of primary production can result in significantly reduced fisheries productivity. Targeted habitat repair and restoration has been proposed as a means to circumvent such observed losses, however, such efforts require quantitative links between estuarine habitats and the fisheries they support to be established. *Metapenaeus macleayi* (School Prawn) and *Penaeus plebejus* (Eastern King Prawn) represent two species of prawn that utilise estuarine nurseries throughout their life history. In this study we used stable isotopes to estimate the proportional contribution of common estuarine habitats to the diet of School Prawn and Eastern King Prawn in the Brisbane Water estuary on the Central Coast of NSW. Recent advances in Bayesian modelling allowed for the incorporation of a third isotope tracer: sulfur, as well as carbon and nitrogen. This inclusion allowed for the differentiation of seagrass and saltmarsh in terms of their isotopic signatures, which subsequently allows for more accurate determination of the relative proportions these potential sources of nutrition contribute, which has been a limitation in several estuarine food web studies. The results obtained here demonstrate that saltmarsh is the dominant source of nutrition for these species, providing 29-63% compared to seagrass which provides 3-20%, despite being 3 times as abundant. This suggests that further losses to saltmarsh habitat may have detrimental effects for penaeid fisheries. Conversely, these links also suggest that with targeted habit repair and restoration, fisheries productivity can be dramatically improved.

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Determining the trophic foundations of a salmonid fishery

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Salmonid fisheries in the Snowy Mountains of Australia are an important recreational, social and economic asset. Despite this high value, inconsistent management stemming partly from a lack of understanding has seen recreational fishing success decline in recent years. To contribute to the body of knowledge that will facilitate improved management of this group of fish, the major energy pathways supporting salmonid fishes in Lake Jindabyne and its tributaries were studied. Stable isotope and gut content analysis techniques were employed to characterise the movement of energy towards salmonid fishes in littoral, pelagic and lotic habitats. Littoral margins of Lake Jindabyne were found to be an important foraging habitat for salmonid species of all sampled size classes. Tributaries were less reliant on terrestrial detritus than initially anticipated, placing some emphasis on in-situ primary production. Some connection between lentic and lotic habitats was established, however further fine-scale analysis is needed to strengthen this finding.

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Moray eels biodiversity behavior conservation status and ecological roles on coral reefs

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Coral reefs are structurally complex habitats with complicated food web interactions associated with both predator capture and prey evasion. Predation is a source of direct density-dependent mortality of species which can shape and alter local populations and even community composition. Thousands of hours of Global FinPrint video using baited remote underwater video systems (BRUVS) have been recorded from reefs around the world. This project is specifically investigating footage from the Coral Triangle and Pacific Ocean, including 22 Countries, 111 reefs. Twenty-seven moray eel species have been observed. There are several aims of this project: (1) determine more complete species distributions, (2) gain a broader knowledge on moray eel behavior, including feeding, mating, and species interactions, and (3) examine the relationship between shark abundance and moray eel abundance. Researching moray eels has been difficult since they have highly secretive lifestyles, living mostly sedentary lives in crevices and caves. Moray eels are key mesocarnivores that usually prey on small fish, octopuses, squid, and crustaceans. Morays exhibit a variety of feeding techniques, including a knot tying behavior and the ability to coordinate hunting with other species. Regardless of moray eels being one of the top predators on reefs, they are still vulnerable to being preyed upon by other large animals such as sharks, barracudas, etc. Preliminary data analysis of the Finprint data indicates an inverse relationship has emerged between the abundance of moray eels and the presence of sharks. Even though we know these predator-prey interactions exist, little research has investigated the relationships and interactions between sharks and moray eels.

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Future tropical reefs: what can we expect for fish & fisheries?

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The climate emergency is driving global ocean heating, acidification and disruption of major surface currents. Rolling waves of mass coral bleaching have provided the most dramatic visuals of the consequences of these changing ocean conditions. We are likely to be witnessing a profound rearrangement of tropical reef ecosystems – can we expect them to support diverse and productive fish assemblages into the future? In the wake of mass coral bleaching, macroalgae has been suggested as one alternative group that may emerge to dominate tropical reefs. We compared the productivity of alternate reef states, including coral and macroalgae, and asked whether macroalgal reefs can support diverse and productive fish and fisheries around maritime nations of the Indo-Pacific. The news is both good and bad, but it will be catastrophic if we do not make the right decisions over the near to medium term.

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A kraken great tale about Australian squid

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A molecular analysis of Australian loliginid squid in the genus *Uroteuthis* has been conducted. Partial mitochondrial DNA CO1 and 16S regions were sequenced for 219 individuals and analysed with a further 47 sequences from publically available samples to create a combined phylogeny for the genus. Results confirm that neither *U. chinensis*, nor *U. edulis*, occur in Australian waters. The genus contains several species-complexes complicating taxonomic identification. A COI species barcode gap of 4-5% is proposed for discriminating species in the genus *Uroteuthis*. Applying this gap highlights that the eight currently recognised *Uroteuthis* species would be better characterised as 23 species. Five undescribed species are resolved in northern and eastern Australian waters, including a newly differentiated south-eastern deeper shelf species. Wide-scale sampling and screening of squid has provided greater resolution of species distributions along Australia's east-coast. A sixth undescribed Indonesian species is also differentiated. Next generation sequencing focused on east-coast populations of *U.* sp 3, *U.* sp 4 and *U.* sp 5 has identified distinct genetic stock structure for fisheries management. Results of the molecular analysis are being used to inform complementary morphometric analyses for new species descriptions, and genetic stock structure assessments of this important fisheries resource.

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A macroevolutionary perspective on the distribution of commercially exploited fish species

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Size-selective harvesting of fishes is known to induce large changes in exploited species' phenotypes, including size, age at maturity, and fecundity, yet other possible macroevolutionary implications of this pervasive harvesting remain unexplored. One proposed process that may be occurring is an "anthropogenic filter", where human consumers preferentially exploit fishes with specific phenotypes, ecologies, or habitats. We test this hypothesis by quantifying the phylogenetic distribution of fished species on the largest fish phylogeny assembled with over 11,000 tips. We show that fished species are more closely related to each other than expected. Additionally, we find that although species are exploited across a range of body sizes, exploited lineages still tend to be larger-bodied than unexploited lineages. A large-scale analysis of habitat types also reveals that exploited species tend to occur in reef habitats and in coastal and shallow water systems. These findings are consistent with the "anthropogenic filter" hypothesis, suggesting that human exploitation of fishes could lead to unpredictable macroevolutionary impacts, as well as altered ecosystem function due to changes in the community structure of productive reef and coastal environments. Our results have broad implications for marine conservation efforts to mitigate these potentially negative effects of anthropogenic exploitation.

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Unravelling the taxonomy and identification of a problematic group of sympatric fishes from a tropical lowland river

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The systematics of Flathead Gobies, a complex of large growing benthic fishes of the genus *Glossogobius* subject to considerable identification confusion, were studied using combined nuclear genetic markers, mitochondrial DNA barcoding, morphology and phenotypic evidence from the waterways of tropical northern Australia. Species boundaries were in contrast to that previously reported, with the Tank Goby *Glossogobius giuris* a cryptic species complex represented by two parapatric taxa. All four species recovered were diagnosed in sympatry at primary study sites in the Daly River, then by distinctive genetic and distribution patterns across northern Australia. Each taxon displayed visual characters that will aid field identification. Additional taxonomic complexity was evident, by comparison with DNA barcodes from international locations, suggesting the specific names applicable for three of the four Australian species studied remain unresolved due to the likely presence of endemic species on the Australian plate and confusion surrounding type specimens from localities in India. Although flathead gobies are assumed as widespread and abundant, these data demonstrate that unrealised taxonomic and ecological complexity is evident that may influence assessments of tropical biodiversity, species conservation and the gathering and interpretation of environmental data including assemblage, habitat use and migration patterns. This helps to reiterate the need for taxonomic studies of freshwater fishes, including economically important *Glossogobius* species in developing countries, to underpin management in areas subject to growing and competing demands for water use and development.

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Hybrid vigour in macquarie perch breeding and stocking

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Re-establishing extinct populations is a challenging task for which success can be evaluated most effectively by monitoring over numerous generations. Considering the genetic diversity of the potential source populations is important, because increased genetic diversity can reduce the risk of inbreeding and increase the potential of the re-established population to adapt and persist. However, genetic diversity is often overlooked when management actions are taken to re-establish populations of threatened species. We estimated survival and growth of hatchery-reared stocked juveniles of the threatened Macquarie perch in the rehabilitated Ovens River, Victoria, using length measurements of fish captured during three years of monitoring (2016-2018) and genetic parentage analysis to identify hatchery-produced fish. Because mixing fish from different populations can bring a strong fitness increase, hatchery crosses of parents from different populations, as well as traditional single-population crosses, were performed to produce fingerlings for stocking. We hypothesised that (1) hatchery-produced fish from inter-population crosses (expected to have higher genetic diversity) grow faster than offspring of intra-population crosses (expected to have lower genetic diversity) and (2) offspring of more genetically differentiated parents have higher survival. The genetic distance between parents was a significant predictor of offspring survival, indicating benefits of cross-breeding different populations during stocking. We found no association between genetic diversity and physical growth rate of the fish stocked into the re-established population, but confirmed this growth to be similar to that in natural populations. Our results highlight positive effects of genetic diversity on offspring survival, providing evidence that mixing of stocks from different populations of threatened fish might benefit population re-establishment.

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FishGen: Identifying stocked fish in the Murray-Darling Basin using genetic parentage testing

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The Murray–Darling Basin Plan aims to protect and restore environmental values through improved water management and return of water to the environment. One measure of the success of the Basin Plan will be the recovery of native fish populations – ideally through natural 'recruitment' (i.e. survival of wild-bred fish). However, over 4.6 million freshwater native fish are stocked annually in the Murray–Darling Basin's (MDB) waterways and impoundments. The stocking of native fish therefore represents a large confounding factor for monitoring and evaluation activities that are designed to assess if native fish outcomes from Basin Plan implementation are met. The MDB FishGen program was instigated by a cross-jurisdictional Working Group and uses non-destructive genetic parentage testing to differentiate between stocked and wild-born native fish. The early results of this program focusing on golden perch will be presented.

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Trojan chromosome: a genetic sex ratio manipulation approach to control the pest fish, *Gambusia holbrooki*

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The history of trying to deal with destructive pest-fish species on large spatial scales has to date been ineffective. However, sex manipulation approaches could revolutionize the management of such notorious pests. This work on *Gambusia holbrooki,* a pest fish of concern to Australia, takes a systematic approach of evaluating feasibility, assessing public acceptance and making technical advances on Trojan chromosome (C) as a suitable genetic control option. To determine Trojan C dynamics, a generic model incorporating both genetic and population dynamic determinants for the control of gonochoristic, bisexual vertebrate pests was used. This was complimented by hormonal sex reversal for generating Trojan carriers and application of molecular-genetic tools for identifying a sex marker. Social acceptance was evaluated using a custom designed survey instrument. The results show that Trojan C is not only the most effective—about 10 and 20 times more effective compared to a closest gender distorting recombinant approach in terms of time for eradication and total cost of eradication—but also one that remains environmentally benign, socially more acceptable and technically robust. Both androgen and estrogen treatments effected functional sex reversal in the species and the sex reversed individuals mate and reproduce normally, with comparable offspring survival. Hormonal sex reversal and progeny testing suggests that the species is female heterogametic, which has a significant bearing on the control strategy. The study has also generated sex-specific genetic markers, that assist in rapid and early detection of sex reversed individuals and will be critical for monitoring the progress of this or any other sex manipulation strategy for controlling the species. In conclusion, whilst generating basic knowledge on population and reproductive biology of the species the study has overcome key biological hurdles in preparation for 'field-testing' of the pest control solution, paving way to manage this and many other pest-fish.

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Scaling up to ocean giants: energetics of shark and ray megafauna

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Energetics studies have illuminated how animals partition energy among essential life processes and survive in extreme environments or with unusual lifestyles. Shark and ray (elasmobranch) megafauna play crucial roles as top predators in many marine ecosystems, but are currently among the most threatened vertebrates and, based on historical extinctions, may be highly susceptible to future environmental perturbations. However, our understanding of their energetics lags behind that of other taxa. This includes, crucially, their fundamental metabolic traits – knowledge required to answer important ecological questions and predict their vulnerability to climate change, which may be limited by expanding ocean deoxygenation and declining prey availability. There are few energetics measurements for elasmobranch megafauna – the heaviest elasmobranch for which metabolic rate has been measured is only 47.7 kg, despite many weighing >1,000 kg. We briefly review the utility of energetics studies in terrestrial and marine megafauna, and highlight several methodological advancements that would enable development of bioenergetics models that can be applied to elasmobranch megafauna. Larger respirometry chambers and swim-tunnels have allowed measurements of metabolism of incrementally larger sharks and rays, but laboratory systems are unlikely to be suitable for the largest species. Advances in biologging tools and modelling will help improve our understanding of energy use in this group and answer pressing ecological questions about these iconic species.

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How do coral reef fishes develop into athletes?

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Locomotion is a universal performance trait that characterises many crucial activities performed by animals, including foraging, reproduction, predator-prey interactions, and daily/seasonal movements. However, some animals perform at higher capacities than others, anecdotally being referred to as 'athletes of the animal kingdom'. While many animal athletes are well known, such as the cheetah, some of the most impressive performers live on the Great Barrier Reef. Indeed, reef fishes play important ecological roles that support coral reef health, however, adult fishes are generally site-specific. Their larvae, on the other hand, develop out in the ocean and return to the reef, not solely relying on oceanic currents, but rather using their elite swimming abilities. Indeed, the larvae of most reef fishes exceed the swimming speed of temperate fish larvae, such as cod and herring, by 10-50 times. Since at least the 1990s, marine scientists have been interested in the impressive swimming capabilities of reef fish larvae, and the impact such performance has on their ability to navigate back to the reef. However, how does an animal early in its development perform at such a capacity, while simultaneously supporting other crucial physiological processes required early in life like tissue growth and basic maintenance? How can we study these miniature athletes? In this talk, I will discuss the challenges of designing equipment to simultaneously measure the swimming performance and oxygen uptake rates, a proxy for the energy required for growth, swimming and maintenance, of larval coral reef fishes over their entire larval phase. Overall, I hope to use these superb swimmers as a model for impressive swimming capabilities in the animal kingdom, and to apply this knowledge to further our understanding of how reef fishes support swimming in their early life history that enables them to locate a suitable reef to live on.

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Taking the heat: understanding organismal responses to eutrophication and climate warming in tandem

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Anthropogenic eutrophication is the world's most widespread form of aquatic habitat degradation and the frequency and intensity of eutrophication events are predicted to surge under climate warming. Yet, it remains unknown how aquatic species, particularly fish, will respond to simultaneous exposure to elevated temperatures and eutrophication. We investigated how an ecologically valuable fish species, European grayling (*Thymallus thymallus*), responds to combined exposure to heat wave conditions (+4°C) and nitrate pollution. A 2 × 3 factorial experimental design was implemented, with fish exposed to one of two temperatures (control: 18°C or a heat wave scenario: 22°C) and one of three levels of nitrate pollution (0, 50 or 200 mg l^{-1}) for five weeks. Following treatment exposure, a range of performance metrics (aerobic scope, hypoxia tolerance, critical thermal maxima, growth and blood oxygen carrying capacity) were assessed to disentangle the interaction between elevated temperatures and nitrate pollution. Our findings shed light on the unintuitive interactions between these stressors, and the trade-offs associated with inhabiting warming, polluted waters.

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Thermal developmental plasticity in fish

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Fishes are sensitive to their thermal environment, and face an uncertain future in a warming world. Theoretically, populations in novel environments might express greater levels of phenotypic variability to increase the chance of surviving – and eventually thriving – in the new conditions. Most research on the effect of the early thermal environment in fish species focuses on average phenotypic effects rather than phenotypic variability, but to understand how fishes will respond to rising temperatures we need to consider both the average response of the population, as well as the breadth of individual responses. Here we present the first meta-analysis on the effects of developmental temperature in fishes. Using data from 43 species and over 6,000 individual fish we show that a change in developmental temperature induces a significant change in phenotypic means and variability, but differently depending on whether the temperature is increased or decreased. Decreases in temperature (cool environments) showed a significant decrease in phenotypic means and no change in phenotypic variability. Increases in temperature (warm environments) showed a non-significant increase in phenotypic means, and a significant increase in phenotypic variability. Larger increases in temperature saw greater increases in phenotypic variability, but no increase in the mean phenotypic response. Together, our results suggest that fishes exhibit both directed and stochastic developmental plasticity in response to warming temperatures, which could facilitate or accelerate adaptation to a changing environment.

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Mitigation of cold water pollution: effects on larval fish growth and development

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Hypolimnial releases from large thermally stratified reservoirs can severely modify downstream river thermal regimes by reducing water temperature. This 'cold water pollution' can often be 12-16°C cooler than natural river temperatures, with effects persisting for hundreds of kilometres downstream of reservoirs. Temperature is an important determinant for many ecological processes; cold water pollution has created river conditions that are unsuitable for populations of native fish, resulting in vast population declines across the globe. Reduced spawning and reproductive success, reduced growth rates and reduced swimming ability have been observed in fish affected by cold water pollution. In Australia, water temperature in the Macquarie River can be reduced by as much as 16°C. A novel, cost-effective 'thermal curtain' has been installed at Burrendong Dam to reduce the effects of downstream cold water pollution and benefit fish populations in the catchment. The goal of this research was to determine how cold water pollution affects the growth and development of three species of native Australian larval fish (trout cod, silver perch and golden perch), and examine the success of mitigation for fish populations. Larval fish growth was severely impeded at low temperatures, particularly in silver perch and trout cod, highlighting the importance of mitigation of cold water pollution. Results are applied to determine targets for future mitigation works and determine the success of current mitigation. Demonstrating the success of mitigation infrastructure such as the thermal curtain implemented at Burrendong Dam could result in similar structures being used to mitigate cold water pollution in other affected regions.

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The rate of physiological acclimation to low temperatures: Is physiological plasticity sufficient for fish to respond to cold water pollution?

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Increasingly, cold-water pollution (CWP) is being recognized as a significant threat to aquatic communities downstream of large, undershot dams in Australia. CWP events typically occur during summer when undershot dams release unseasonably cold and anoxic hypolimnetic waters, which can alter the temperature of downstream waters by up to 16°C. Depending on the release duration, these hypothermic conditions can last for many months. The capacity of ectothermic species to tolerate or rapidly acclimate to acute temperature changes may determine the nature and magnitude of the impact of CWP on affected species. We used an experimental approach to assess the impacts of an acute reduction in water temperature on the physiological function and locomotor performance of juvenile silver perch (*Bidyanus bidyanus*) and examined their capacity to thermally compensate for the depressive effects of low temperatures via phenotypic plasticity. Locomotor performance (*U*crit and *U*sprint) and energetic costs (routine and maximum metabolic rate) were measured at multiple points over a ten week period following an abrupt 10°C drop in water temperature. We also measured the thermal sensitivity of metabolic enzymes from muscle samples taken from fish following the acclimation period. We provide valuable data on the physiological response of fish to temperatures similar in magnitude to CWP events, and highlight substantial implications for the management of cold water releases from large scale dams and the conservation of native freshwater fish species.

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The effects of heatwaves and ocean acidification on a juvenile reef mesopredator, *Chrysophyrs auratus*

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As anthropogenicaly driven climate change advances, coastal marine ecosystems are predicted to experience increasingly frequent and intense heatwaves, which will occur in association with ocean acidification. Changes to temperature and CO_2 levels beyond the usual conditions can present significant stress to marine organisms, especially if they occur during critical early life history stages; however their effects on ecologically and economically important mesopredators are relatively understudied. We used a fully cross-factored experiment to test the effects of elevated temperature (+4°C) and CO_2 (1000 µatm) on the aerobic physiology and swimming performance of juvenile snapper, Chrysophrys auratus. Both elevated temperature and elevated CO_2 increased resting metabolic rate, meaning elevated daily metabolic costs. By contrast, maximum metabolic rate was increased by elevated temperature and decreased by elevated CO_2. The differential effects of elevated temperature and elevated CO_2 on maximum metabolic rate resulted in the aerobic scope being reduced only in the elevated CO_2 treatment. Critical swimming speed also increased with elevated temperature and decrease with elevated CO_2, matching the results for maximum metabolic rate. Elevated CO_2/low pH events already occur in the coastal habitats that larval and juvenile snapper occupy, and these events will be exacerbated by ongoing ocean acidification. Our results show that elevated CO_2 in coastal habitats negatively affected a broader range of traits than heatwave conditions for juvenile snapper, which could reduce their overall fitness and potentially have negative consequences for population recruitment.

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Nutrient pollution, high temperatures and fish kills: How physiological and experimental approaches can assist in predicting future mortality events?

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Australia's Murray Darling Basin experienced successive fish kill events (major mortality events) in the summer of 2019. The fish kill events were the result of elevated nutrient levels, stimulated algal growth, high temperatures and low water flows, all of which combined to create an inhospitable environment for many fishes. Despite the numerous, simultaneous challenges being faced, data on species responses to multiple environmental stressors are scarce. Here, using an experimental approach, we examined the combined effects of elevated temperatures and nitrate pollution on the threatened freshwater fish, silver perch (*Bidyanus bidyanus*). Fish were exposed to either current-day summer temperatures (28°C) or forecast future summer temperature (moderate warming; 32°C) in combination with one of three nitrate concentrations (0, 50 and 100 mg/L). After six weeks of acclimation, we measured a series of physiological tests including aerobic scope (i.e. maximal – routine oxygen uptake), blood –oxygen carrying capacity and whole animal performance traits (growth and swimming capacity) to understand how fish are affected by the interaction between nitrate pollution and warming. We provide valuable data on the responses of silver perch to the combined effects of elevated temperatures and nutrient pollution, and information on whether water quality guidelines need to be made more stringent under forecasted climate change to prevent future fish kill events.

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Lessons from fish kills outside of the Murray-Darling Basin: Tracking recovery of the Katherine River fish assemblage after the 2012 hypoxic blackwater event

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Recent mass fish kill events in the Murray-Darling Basin (MDB) have highlighted the need to understand how these seemingly catastrophic events impact fish assemblages in both the short and the longer term. In 2012, a large hypoxic blackwater event in the Katherine River, Northern Territory, resulted in a major fish kill affecting a wide range of fish species over ~30 river km. The event occurred at a site that has been monitored twice per year for six years pre- and now, six years post the fish kill event.

The immediate effects of the fish kill were significant, while the fish assemblage and has been altered taken many years to recover. Mean species richness was lower after the event for many years, however mean total fish abundance increased post event. The fish assemblage was significantly altered by the fish kill in both the short and long term. Response to the event, and subsequent recovery varied among species; and could be aligned with life history traits of the fish. The Katherine River largely retains its natural flow regime, contains no artificial barriers to fish movement, and has no exotic fishes. We use this is a model system to explore and predict recovery patterns from fish kills under near 'natural' conditions and hypothesise how this may influence recovery in other modified systems.

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Can stocking play a role in recovering fish populations after fish kills? - Lessons following blackwater events in the Edward-Wakool river system

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Localized catastrophic events can dramatically affect fish populations. Management interventions are often undertaken to re-establish populations that have experienced such events. Evaluations of the effectiveness of these interventions are required to inform future management actions, and knowledge of the recovery pathways contributing to successful restoration are an essential component. Multiple hypoxic blackwater events in 2010–2011 substantially reduced fish communities in the Edward-Wakool river system in the southern Murray-Darling Basin, New South Wales, Australia. These events led to extensive fish kills across large sections of the entire system following a period of prolonged drought. To expedite recovery efforts, golden perch *Macquaria ambigua* and Murray cod *Maccullochella peelii* fingerlings were stocked at five locations over 3 years. All fish stocked were chemically marked with calcein to enable retrospective evaluation of wild or hatchery origin. Targeted collections were undertaken 3 years post-stocking to investigate the relative contribution of stocking efforts and recovery via natural recruitment in the system. Of the golden perch retained for annual ageing (n = 93) only nine were of an age that could have coincided with stocking activities. Of those, six were stocked. The dominant year-class of golden perch were spawned in 2009; before the stocking programme began and prior to blackwater events. All Murray cod retained (n = 136) were of an age that coincided with stocking activities, although only eight were stocked. Among the Murray cod captured, the dominant year-class was spawned in 2011, after the blackwater events occurred. The results from this study provide evidence that natural spawning and recruitment, and possibly immigration, were the main drivers of golden perch and Murray cod recovery following catastrophic fish kills. Interpreted in the context of other recent examples, the collective results indicate minor benefit of stocking to existing connected populations already naturally recruiting in riverine systems.

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Murray cod in the lower Darling River: environmental flows protect populations

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The 510-km lower Darling River (LDR) supports a strong Murray cod population and is a major dispersal pathway for golden perch recruits from the Menindee Lakes nursery grounds to the southern Murray-Darling Basin (MDB). To maintain self-sustaining populations, Murray cod require perennial flows but from 2013-2016, there were low/zero flows from Menindee into the LDR and very little recruitment. In August 2016, a flood event in the upper Darling enabled a multi-agency team to deliver water from the Menindee Lakes into the LDR and lower-Murray River, including the first ever environmental flow for the LDR. The planned flow occurred over 24-months and matched Murray cod and golden perch spawning/recruitment requirements. Conceptual life-history models informed the flow regime, including: (i) spring rise with a steady peak for Murray cod nesting/spawning, (ii) a flow pulse to cue golden perch spawning and maximise out-migration of recruits from the Menindee Lakes nursery grounds; (iii) elevated flows throughout spring/summer to inundate low-lying benches and promote food/habitat resources for young fish, (iv) a slow autumn flow recession to a permanent winter baseflow. Hundreds of Murray cod larvae were present in the LDR during spring 2016 and 2017, with boat electrofishing surveys 24-months later demonstrating high survival. Fish spawned during the environmental flow represented ~30% of the overall population for Murray cod and golden perch. To protect and recover LDR native fish, we present a flow delivery model for permanent implementation; it can also be applied to other rivers. Following the recent Menindee fish kills, there is an urgent need for a 10-year *perennial* flow delivery strategy which requires multi-agency and community collaboration. A key will be better protection of small and medium tributary inflows along the entire length of the Darling-Barwon River.

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Rehabilitating fish populations in the Barwon-Darling: an ecohydraulic perspective on fish kills and the future.

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Recent fish kills in the lower Darling River have brought global attention to the ecological health of rivers in the MDB. The Barwon-Darling river system is characterised as one of the most hydrologically variable in the world. Yet these rivers sustained aboriginal people for at least 50,000 years, with middens along the Darling River composed predominantly of mussels and snails characteristic of perennial flowing water. This contrasts with a common perception of the Barwon-Darling as an unpredictable, ephemeral, dryland river system. Drought and low flows are not atypical in the Barwon-Darling river system, so what has changed, why have lotic species been lost from rivers of the region and what contributed to recent fish kills? Here we integrate historical and contemporary ecology, hydrology and hydraulics to provide an insight into ecological decline in the Barwon-Darling system and importantly, an ecohydraulic premise for rehabilitation.

The three most extreme droughts on record (1895-1903; 1935-43; 2001-09) which are pre- and post-1960's irrigation development, provide context. Zero-flow periods are arguably unchanged in extreme droughts, but the magnitude of low flows is drastically reduced post-diversions. Indeed, the Millennium Drought (2001–09) and 2018-19, have the longest continuous periods without flowing-water (lotic) habitats in the 134 year record. These data indicate the impact of diversions far outweighs drought and climate change. Increased still-water (lentic) conditions, caused by extreme low flows, are exacerbated by weir-pools, which combined with increased anthropogenic sources of nutrients increases the risk of cyanobacterial blooms and their attendant impacts.

Water velocity data show that relatively low flows (e.g. 200–300 ML/d) in the Darling River are sufficient to promote a flowing-water ecosystem and protect lotic mussels, snails and fish in droughts. These flowing-water conditions also provide a key mitigation for cyanobacteria, but increased risk of stratification in deep weir-pools needs to be addressed.

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Fish kills: we have been there before, we know what to do, what's the hold up?

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Fish kills are not nice but not new; though are occurring with greater intensity and regularity. Responses usually follow the same pattern: shock, horror, publicity, governmental spin, enquiry, recommendations, then minimal action. Major kills back in 2004 (Broken creek and Darling river) were extensively examined with priority actions recommended (Murray cod MDBC workshop and recovery plan). The 2019 Darling river kills provided graphic photos of millions of dead fish, caused major publicity and public outcry and resulted in two public enquires in addition to a SA parliamentary inquiry into water management. The response to date has been the allocation of $5 M to develop a Native Fish Recovery Management Strategy with a potential further $70 M (equivalent to one freeway overpass) for remediation measures. Is this enough? Given the recognised poor state of Murray-Darling fish populations (estimated to be at 10% of pre-European levels), the question is not about fish kills, but whether we seriously wish to recover MDB native fishes? Fish kills are just the horrible result of poor management. Do we know the problems? Yes-an existing Native Fish Strategy currently unfunded but being revisited, provides a forward plan. How much is needed? Given $13 B has been allocated to environmental water to improve a range of biota under the Basin Plan perhaps a figure equivalent to 10% of this ($1.3B) would be a realistic start to address other fish recovery actions? This is about the same as 1.5 years expenditure by recreational anglers. So, in summary, $1.3B, a revised plan, backed by commitment and oversight by the MDB states, with great social and economic benefits to rural communities, in conjunction with the Basin Plan will go a long way to recovering native fish populations and preventing future kills!

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Utilisation of a recovering wetland by a commercially important species of penaeid shrimp

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Estuaries contain a mosaic of habitats supporting numerous ecosystem services, including food and habitat, but also represent an important association for many commercial and recreational species. However, modifications to hydrological flow has degraded the quality of many saltmarsh wetlands, potentially threatening fisheries productivity. Penaeid shrimp represent an important group of valuable exploited species known to either directly utilise saltmarsh habitat, or utilise saltmarsh-derived productivity. As such, both areal coverage and primary productivity of saltmarsh habitat has direct consequences for fisheries productivity, and they are likely to be key beneficiaries of habitat repair. This study aimed to establish quantitative estimates of abundance and nutritional support of School Prawn, *Metapenaeus macleayi*, across a recovering wetland system. Six surveys were conducted across the wetland using a specialised benthic sled, and absolute abundance of School Prawn was estimated. The movement of carbon and its assimilation by School Prawn was measured using stable isotopes. There was asymmetry in the abundance of School Prawn across the wetland, with consistently more abundance in certain areas of the wetland (the highest abundance site supported 1017 prawns per 100 m^2), and the average density across the wetland was 244 prawns per 100 m^2. All areas of the wetland (except the area closest to the wetland mouth) supported the full range of size classes, and multiple cohorts of prawns moved through the system during the sampling program. A Bayesian isotope mixing model indicated that saltmarsh contributed up to 28% of School Prawn diet, however, mangrove and fine benthic material were dominant. These results show that the recovering wetland is supporting a high abundance of School Prawn. Our estimates of recruitment for School Prawn will also be useful in gauging the potential increases in fisheries productivity arising from habitat repair in this, and other systems.

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Novel video-based observations of shark depredation and behavioural interactions with fishing gear

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Shark depredation, where sharks consume hooked fish, causes increased mortality for target species, injury to sharks and the loss of fishing gear. In Western Australia, the shark species involved in depredation and how they behave around fishing gear is largely unknown. To address these knowledge gaps, we deployed line-mounted video cameras in a recreational fishery in the Ningaloo region of Western Australia to identify shark species responsible for depredation, investigate their behavioural interactions with fishing gear, determine the prevalence of retained fishing gear in sharks and quantify the influence of environmental variables and fishing methods on shark abundance during demersal fishing at 92 locations. We recorded a shark depredation rate of 9.1%, and sicklefin lemon *Negaprion acutidens*, blacktip/Australian blacktip *Carcharhinus limbatus/tilstoni*, grey reef *Carcharhinus amblyrhynchos* and spottail *Carcharhinus sorrah* sharks were observed depredating lethrinid and epinephelid fishes. Five additional shark species from four families were also recorded interacting with fishing gear, but they did not depredate hooked fish. Sharks were observed interacting with fishing gear in a number of ways, and these behaviours were classified by compiling a detailed behavioural ethogram. Key behaviours included where sharks investigated baited hooks and other fishing gear components and where they followed the fishing gear as it was being retrieved. The relative abundance of sharks at each fishing location was influenced by longitude, sea surface temperature and total number of fish hooked. By identifying the shark species responsible for depredation and investigating their behavioural interactions with fishing gear, this study

provides important insights that have broader significance to other fisheries, particularly for developing effective deterrents to mitigate shark depredation and bycatch.

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Stock assessment of Australian east coast spotted mackerel (*Scomberomorus munroi*): predictions of stock size and impacts of environmental variation

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Australian east coast spotted mackerel (*Scomberomorus munroi*) are a pelagic fish species forming a single genetic stock across New South Wales and Queensland waters. It is a popular recreationally and commercially caught species throughout Qld and in northern NSW. Understanding trends in stock size are required to effectively manage this species and ensure its ongoing sustainability. We have assessed the population size of east coast spotted mackerel using an age structured population dynamics model. This analysis was used to determine changes in stock size through time, along with current biomass and harvest target estimates to inform fishery management. Our analyses revealed declines in population size to between 20 to 40% of unfished biomass (1961), in the early 2000s. This decline corresponds with high fishing pressure, predominantly resulting from commercial ring netting, a popular fishing method at this time. In 2002, limits on netting spotted mackerel were introduced, reducing commercial fishing pressure. This reduced fishing pressure has resulted in an increase in stock size. However, recovery has been slower than anticipated with reduced fishing pressure and relatively resilient life history traits. This suggests that other variables may be influencing population size. To improve our understanding of additional pressures on stock size, we have investigated relationships between environmental variables and the abundance of spotted mackerel. Increased awareness and understanding of the impacts of changing environmental conditions and spotted mackerel abundance will allow for improved management and ensure the stock is sustainably harvested into the future.

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Understanding oceanographic and environmental factors impacting the Eastern Tuna and Billfish Fishery

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Sustainable fisheries management is aided by holding accurate knowledge of the distributions of target species, and of potential distribution shifts resulting from changing conditions in the oceans. The Eastern Tuna and Billfish Fishery (ETBF) operates in a known hotspot of marine climate change. A key uncertainty in interpreting historical catch in the ETBF, and in potential prediction of future catches, is the influence of the physical environment on the spatial distribution of target species. There is a need to understand how ocean climate events are associated with movement of fish cohorts into the region, and how (sub-)mesoscale oceanographic conditions influence fish movements within the domain of the ETBF. Our project therefore seeks to (i) assess the influence of broad-scale ocean climate drivers on catch rates, and (ii) develop dynamic habitat models for the five key target species of the ETBF (yellowfin tuna *Thunnus albacares*, bigeye tuna *Thunnus obesus*, albacore tuna *Thunnus alalunga*, broadbill swordfish *Xiphias gladius*, striped marlin *Kajikia audax*) in Australian waters, and for the wider South Pacific. We aim to use resultant models to generate seasonal forecasts of fish distributions using physical data fields from forecasting tools ACCESS-S (Bureau of Meteorology), and the Climate Analysis Forecast Ensemble (CAFE, CSIRO). We will also compare the predictions of different types of habitat models, and assess model transferability between domains. Together, these innovations will help to facilitate industrial adaptation to climate change impacts in Australia and the South Pacific, which is vital for future food security and the regional blue economy.

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Fishing smart: using biological and economic information to direct abalone harvest strategies

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Recent declines in the productivity of wild abalone populations around Australia are leaving fisheries with declining profitability and uncertain sustainability. For example, over the past five years, Australian abalone production has decreased by 24%, there has been an associated decrease in profit and, in 2018, 63% of the stocks had a classification of “depleting”.

Using the Western Zone of South Australia as an example, we investigate ways to help mitigate these changes by “fishing smart”. We use a two-pronged approach – (1) application of knowledge on the seasonally variable biology of abalone to increase fishing efficiency, and (2) review of the economic benefit of alternative fishery strategies that include changing fleet size and the fishing season.

We demonstrate that the profitability of fisheries can be improved by increasing fishing efficiency. Using a seasonal steady-state model, we show that information on the seasonally variable biology of greenlip and blacklip can be used to increase revenue, reduce exploitation rates, or achieve a combination of these two management objectives. This is because both species weigh more and bleed less at certain times of the year. The outputs identify clear economic and biological benefits to altering monthly fishing effort for both species. Building on biological information, we also consider the economic benefit of different fishing strategies. This cost-benefit analysis is achieved by contrasting the outcomes of restructure scenarios that involve combinations of changes in fishing season and fleet size with a baseline (status quo).

Our study demonstrates that (1) there can be considerable benefits to fishing during specific months of the year, and that the magnitude and period for optimal fishing does vary depending on species and (2) as the total allowable commercial catch for the abalone fisheries decreases, the profitability of the fisheries can benefit considerably from reductions to the fleet size.

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From teleosts to elasmobranchs, Sanger to Illumina; using genetic data from the Australian National Fish Collection

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At ASFB 2016, we highlighted the ANFC and our ongoing taxonomic validation and development of mtDNA barcoding reference sequences for rapid species identifications, informed phylogenetic analyses and increased species discovery. In the Barcode of Life Database (BOLD), we curate over 13 000 cytochrome oxidase subunit I (COI) sequences from Indo-Pacific temperate and deep-water fishes and sharks. This extensive genetic resource is now being utilised in three CSIRO Environomics Future Science Platforms which a) assess DNA for fish identifications from formalin preserved specimens; b) investigate fish communities from Tasmanian waters using environmental DNA (eDNA); and c) examine analytical issues in bioinformatics data sets. We employed fish specific (2 × COI and 16S) and a broader metazoan (COI) mini-barcode amplicon assays in single-source good quality and formalin degraded DNA samples and filtered water samples. For single-source samples, metabarcoding on an Illumina MiSeq platform was compared to Sanger sequencing while community eDNA metabarcoding was undertaken solely on the MiSeq. Development of new bioinformatics processing pipelines for the ANFC specimens and eDNA samples, coupled with our reference sequences have shown that a) fish preservation in formalin is not always an insurmountable hurdle for DNA analyses; b) Sanger sequencing still has a role to play for reference sequence generation; c) appropriate amplicon choice for Illumina metabarcoding of taxa of interest is essential; d) utilisation of and identification accuracy in reference sequence databases matter; e) selection of taxonomic classification algorithms and parameters are important; and f) as an emerging tool for fish biodiversity assessment, eDNA results should be validated and cross-checked with occurrence observations.

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Identifying fish predators to mitigate Crown-of-Thorn seastar outbreaks

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Population outbreaks of the Crown-of-Thorn seastar (CoTS), *Acanthaster* cf. *solaris*, have resulted in a significant decline in coral cover on the Great Barrier Reef (GBR). Release of predation pressure remains one of the most likely hypothesised influences on CoTS population dynamics. To inform management of CoTS predators, we aim to identify fish species that predate on different life history stages of CoTS on the GBR. We have developed a highly innovative and non-invasive method to identify CoTS DNA in fish faeces, and successfully applied this in both laboratory and field settings. Specifically, we are applying a genetic marker, developed to identify *A.* cf. *solaris* larvae in seawater, to identify potential fish predators of CoTS that may be important as natural controllers. Fish species of interests are those that may prey on larval, post settlement and adult CoTS. So far, CoTS DNA has been confirmed in faecal matter of smaller planktivorous damselfish species and a range of larger carnivorous fish species, suggesting predation by fish may play a role in reducing CoTS larval abundance, settlement and post-settlement survival. Future work will examine potential linkages between fisheries' catch records and CoTS outbreaks. Overall, this work will inform CoTS management by recommending approaches around the use of predator manipulation in mitigating CoTS outbreaks.

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Corallivores as potential indicators of coral reef health: diet and microbiome

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Approximately 75% of coral reefs are threatened by climate change, human stressors and rising sea temperatures. Scientists and managers worldwide seek accurate and reliable indicators that represent the health of these sensitive ecosystems. Corallivores, such as butterflyfish, are one group of organisms that may serve as an early indicator of reef health. Furthermore, coral-associated microbes are intimately linked to host health and respond rapidly to environmental changes, suggesting they may also be useful bioindicators. Here, we aimed to test the utility of obligate corallivores as an indicator for reef health. Specifically, we constructed a habitat assessment tool for coral reef health and determined if the microbiome of the butterflyfish *Chaetodon lunulatus* reflected levels of impact within reef habitats. At nine sites, *C. lunulatus* were collected for microbial and stable isotope analysis, abundance and diversity of fish and coral were recorded, and feeding behaviour of *C. lunalatus* was observed. The V4 region of the 16S rDNA gene was sequenced and the stable isotope content of fish muscle, coral and symbiotic zooxanthellae were analysed. A habitat assessment tool was successfully applied to the sites which were identified as ranking from low to high impact. *Chaetodon lunalatus* fed predominately on corals from the family Acroporiidae and Poritidae, and there were no differences in alpha diversity within the gut microbiomes of *C. lunlatus* at the various sites. However, beta diversity of microbiomes differed between sites, with low impacted sites less variable in comparison to highly impacted sites. Stable isotope analysis indicated that fish and coral within high impact sites had shifted a tropic level higher in nitrogen versus those inhabiting low impact sites. This data indicates that the gut microbiome of an obligate corallivore is an effective and sensitive bioindicator for coral reef health, providing additional information above traditional methods for monitoring reef health.

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The development of eDNA metabarcoding to assess fish biodiversity in coastal ecosystems and integrating these data into marine monitoring programs

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The emerging field of environmental DNA (eDNA) is transforming our approach to how we assess biological diversity and ecosystem function. eDNA is used to describe DNA shed from secretory processes such as the sloughing of skin, scales, mucus, eggs, sperm, blood, or defecation, and can be used to provide a record of a species presence. When combined with recent advancements in next-generation sequencing and bioinformatics, the diversity of organisms from environmental samples that contain mixtures of DNA signatures can be recovered. As such, eDNA metabarcoding can provide a wealth of information for studies of fish biodiversity, food web dynamics, diet analysis, and for environmental and invasive species monitoring. We here highlight a number of studies based on coastal ecosystems across Australia, thus focusing on the development and application of eDNA metabarcoding for studying fish biodiversity across spatial and temporal scales, as well as methods development around laboratory protocols and taxonomic assignments. We additionally highlight how these advances might be incorporated into existing or new marine monitoring programs as well as international diplomacy.

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Using eDNA to corroborate predicted distributions of threatened fishes

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The existence of threatened species of fish presents a significant risk in relation to insufficient water for the environment. New South Wales Fisheries have modelled the spatial distribution of threatened fish species in the Murray Darling Basin using Maxent modelling, which predicts the probability of a species occurring in a particular location based upon its preferred habitat. Given the presence of these species has the potential to influence changes in water access rules, or the use of scarce environmental water entitlements, it is crucial that this modelling is verified. Environmental DNA (eDNA) relies on detecting trace amounts of DNA species release into the environment to infer their presence in an area. eDNA has proven itself to be a valuable survey technique, capable of detecting species at extremely low densities, frequently with greater sensitivity than traditional survey methods. Here, we present results of recent multi-species eDNA surveys in the Murray Darling Basin and identify the concordance between the predicted distributions and eDNA detections for eight key threatened taxa.

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eDNA metabarcoding in the offshore and coastal waterways of the Kimberley, WA

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The Kimberley coastline is a renowned marine biodiversity hotspot with over 1500 documented fish species. Safety concerns with hazardous fauna (i.e. saltwater crocodiles, sharks and jellyfish) and the high turbidity of Kimberley waterways has, however, limited the use of observational surveying techniques for ongoing marine monitoring. In this study, we applied eDNA metabarcoding for the first time in the Kimberley region as a potential non-invasive and non-observational genetic solution to broad-scale surveying. Seawater samples were collected from 71 sites across approximately 1,350 kilometres of Kimberley coastline. Metabarcoding assays targeting the mitochondrial 16S and COI regions were developed and/or optimised to target a wide range of bony fish, elasmobranchs and aquatic reptiles. Over 400 taxa were detected from the collected seawater samples, revealing unique community compositions, habitat preferences and latitude transitions across this vast region. Notably, we provide updated distribution information for endangered and data-deficient elasmobranchs, such as sawfish (family Pristidae) and the Northern river shark (*Glyphis garricki*). We have, at present, conducted the largest geographical eDNA study for marine species detection and demonstrate the utility of eDNA metabarcoding to provide fine-scale compositional data across a broad-scale study area. With increasing pressure from natural resource extraction, recreational fishing and tourism, key biodiversity information such as that provided by eDNA techniques is required to implement targeted management programs in this remote region.

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Methods for maximising tropical fish alpha diversity measurements using eDNA metabarcoding

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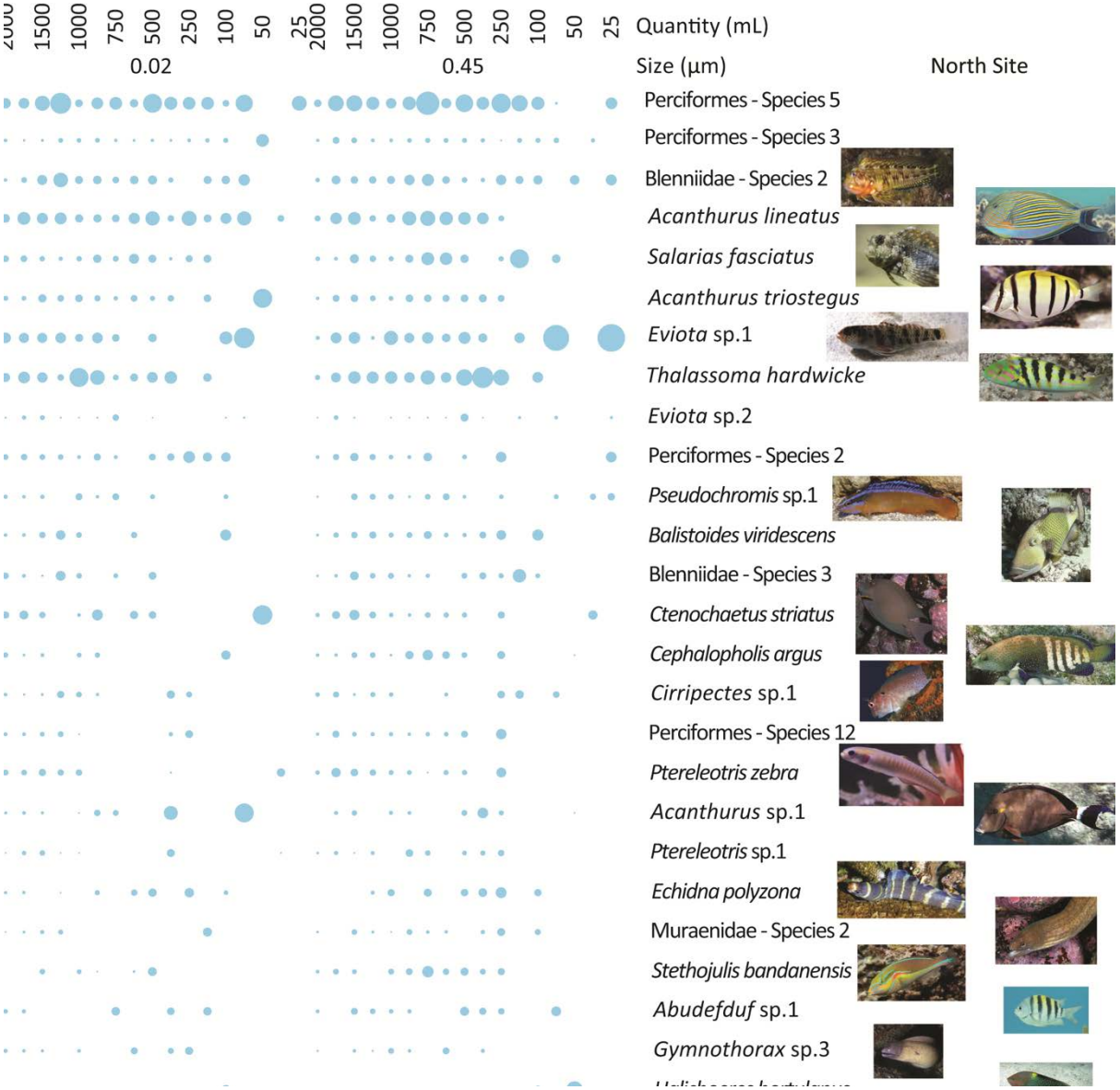
The management of fish biodiversity relies on accurate understandings of species distributions and abundances over time. Molecular genetic techniques are now being employed to describe fish assemblages by extracting free DNA from the marine environment. Environmental DNA (eDNA) is continuously expelled by organisms through a variety of avenues (e.g. excreted cells, tissue, faeces, or as microscopic egg and larvae). eDNA is a relatively new technique and its full capabilities and methods for best practice deployment are an active area of research. The objective of our study was to determine how water sampling volumes and filter pore sizes dictate metrics of marine fish biodiversity at a tropical coral atoll in northern Australia. We also compare the estimates of fish biodiversity recovered through eDNA analysis with those observed previously by conventional survey techniques. Water samples were collected from two sites during high tide on the intertidal reef of Browse Island; a tropical, remote offshore island in the Browse Basin, Timor Sea. Aliquots from a single ~20L sample and multiple 2L samples were immediately filtered in various volumes (25mL to 2000mL) across two membrane sizes (0.20µm and 0.45µm). A single fish metabarcoding assay approach was used to investigate the fish diversity between aliquots. All samples, except for one, yielded DNA sequences. After sequence processing, 209 OTUs representing 49 fish families were assigned from the complete collection of DNA contained in all samples. Previous studies conducted at this location using traditional fish surveys detected approximately ~150 fish species. Our results support mounting evidence that eDNA analysis can characterise fish biodiversity in comparable detail to conventional survey methods, as well as expand our understanding to previously poorly represented taxa. Yet, they also demonstrate that the potential of this next-generation biodiversity survey tool will be maximised if greater attention is applied to sampling protocols.



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Exposure to elevated pCO_2 affects the cardiac performance of cobia, *Rachycentron canadum*

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Carbon dioxide (CO_2) emissions into the atmosphere, a third of which are absorbed by the oceans, are decreasing ocean pH at an unprecedented rate. Teleost fishes, which occupy nearly every body of water and span a diverse range of environmental conditions, have typically been able to maintain

or even increase performance under elevated partial pressures of CO_2 (pCO_2). Their success has, in part, been attributed to their unique oxygen transport system. However, there has been limited research examining other possible mechanisms contributing to fishes physiological success during exposure to elevated pCO_2. To further examine fishes physiological processes during these exposures we decided to look at cardiac performance. To these authors' knowledge, there is no research examining cardiac performance during pCO_2 exposure. In order to examine this, a pelagic fish species, cobia (*Rachycentron canadum*), was either exposed to elevated (~1,200 µatm) or ambient pCO_2 for three weeks. Following exposure, cardiovascular performance, oxygen uptake rates, and swimming performance were measured simultaneously using swimming respirometers. Cobia exposed to elevated pCO_2 demonstrated higher cardiac output and stroke volume than their counterparts held at ambient conditions regardless of swimming speed. This suggests that pCO_2 exposure, rather than the swimming trial, had a greater effect on the cardiac performance of cobia. Additionally, oxygen uptake rates were also elevated in fish exposed to elevated pCO_2; however, this also varied with swimming speed. This is the first study to measure the cardiac performance of fishes exposed to elevated pCO_2. This data suggests that, although we often see little to no physiological effect of pCO_2 during swimming trials, there may be unmeasured physiological consequences not taken into account. Which further begs the question, what does this extra energy requirement mean for large pelagic fishes?

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Anthropogenic noise affects behavioural traits that determine survival in coral reef fishes

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Anthropogenic noise is increasing in marine environments as a result of human activities. The recent recognition of this stressor as a pollutant highlights the necessity of conducting research in order to provide governmental institutions with information for its management and regulation. Although, small motorboat noise has been found to increase mortality in fish the mechanism underlying this process in their natural environments remains poorly understood. Moreover, there is not clear evidence of the negative effects of ship noise on aspects of fish ecology that may affect survival. This study evaluated the effects of ship and motorboat noise on two behavioural traits critical for fish survival in their natural environments, routine activity and escape response. By using an experimental arena, we were able to recreate a predator strike that was constant over trials (a startle stimulus) and allowed us to record the response of fish at high speed under different acoustic conditions. Our results showed that the two noise sources have markedly different effects on reef fishes. Fish exposed to ship noise responded more slowly and moved shorter distances when presented the stimulus compared to individuals exposed to motorboat noise. Our study suggests that ship and boat noise increase the vulnerability of individuals to predation and corroborates that the effects of noise in fish depend on the noise source, highlighting the need to include these two common sources of anthropogenic noise in future management plans.

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Effect of Light Pollution on Diurnal Rhythm of Melatonin in *Catla Catla* and *Labeo Rohita*; Comparative Study in Farm and Indoor Facility Illumination Conditions

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Use of artificial light at night (ALAN) for outdoor illumination has been exceeded in metropolitan, semi urban areas and animal farms including aquaculture research facilities. worldwide. ALAN has caused disruption in natural light and dark periods. These modified day lengths have profound effects on internal body clocks regulated by melatonin. ALAN at indoor research facilities might interfere with the results of scientific trials which have not be fully realized yet. Present study investigated the effects of ALAN on diurnal profile of melatonin at indoor facility/laboratory (artificial light group: AL) compared with that at outdoor farm (natural light group: NL) in *Catla Catla* and *Labeo rohita*. Light intensity was measured to be 5 and 156 lux at farm and indoor facility, respectively. Blood samples were collected over the period of 24 hours. Levels of melatonin in NL group of both species started increasing at sunset (107.44 ± 0.10 pg/ml in labeo; 103.05 ± 1.23 pg/ml in catla). Highest levels were observed at midnight (180.90 ± 0.21 pg/ml in labeo; 175.06 ± 1.30 pg/ml in catla). Hormone profile started decreasing after sunrise and the minimum values were observed at mid-day. Diurnal profile of melatonin did not show any significant variability ($P > 0.5$) in AL group in both species and remained low over the period of 24 hours. This study concluded that ALAN in laboratories and indoor aquaculture facilities disrupts the hypothalamus-pituitary-pineal (HPP axis) and might affect the physiological activities regulated by melatonin in fish.

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Discovery of a specialised anatomical structure in some physoclistous carangid fishes which permits rapid ascent without barotrauma

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Physoclistous fish are unable to rapidly ascend through the water column without significant risk of barotrauma via swim bladder hyperextension or rupture. Here we report on the discovery of a highly-specialised anatomical structure which permits some physoclistous fish species, the samsonfish *Seriola hippos* and silver trevally *Pseudocaranx georgianus*, to vent swim bladder gas during ascent. Dissections of injected casts and X-ray imaging revealed the swim bladder 'vent' to consist of a membranous opening in the roof of the swim bladder which led to a flattened tube that bifurcated around the vertebral column and exited via a small, oval-shaped hole in the pharyngo-cleithral membrane underneath each operculum. Identification of these distinctive holes revealed that venting had occurred on ascent in 96% of in *S. hippos* captured from depth. Decompression from simulated 30 m water depth in an experimental hyperbaric chamber revealed that venting in *P. georgianus* commenced when predicted swim bladder volume was approximately double that of its initial volume and ceased when the fish were again near-neutrally-buoyant. A homologous structure

was identified in *S. lalandi* and *S. dumerili*. This structure represents an important step in the evolution of the teleost swim bladder which circumvents the normal physoclistous restriction on rapid ascents by eliminating, or minimising, barotrauma. Ecological benefits of this ability include an improved ability to capture prey, escape predators and perform 'spawning rushes'. The increased resilience to barotrauma provided by the swim bladder 'vent' may also reduce the levels of post-release discard mortality for deep water species which possess the structure.

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Disentangling intrinsic and extrinsic drivers of otolith chemistry in a coastal marine fish

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Otoliths (ear stones) in fish are valuable chemical repositories of information that address fundamental questions about fish ecology. However, to effectively apply otolith chemistry as retrospective biomarkers, it is important to understand the intrinsic (biological) and extrinsic (environmental) influences on isotopic and elemental incorporation. Significant relationships between physiological characteristics and chemical signatures may indicate that otolith chemistry can reconstruct physiological trends or conversely, cloud the interpretation of environmental histories. As such, we investigated the relationships between otolith chemistry, physiological characteristics, and environmental conditions in an iconic and valuable fishery species, Australasian snapper (*Chrysophrys auratus*). We analysed lifetime profiles in otoliths of stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes using isotope-ratio mass spectrometry (IRMS), and element concentrations of barium (Ba:Ca), strontium (Sr:Ca), magnesium (Mg:Ca), manganese (Mn:Ca) and lithium (Li:Ca) using Laser Ablation Inductively Coupled Plasma-Mass Spectrometry (LA ICP-MS). Samples were taken from wild snapper across two oceanographically diverse regions and three cohorts in southern Australia to examine life history patterns. Mixed-effects modelling was used to investigate the influence of intrinsic factors such as age, otolith growth, fish size and sex; and environmental factors of sea surface temperature and chlorophyll-*a* (indicating primary productivity) on chemical chronologies. We found that intrinsic influences were significant for several isotopes and elements in otoliths, suggesting their potential in reconstructing lifetime physiological trends. In contrast, the remaining isotopes and elements were unaffected by intrinsic characteristics and are suggested as accurate measures of past environmental conditions. Environmental factors were also significant influences on otolith chemistry. The chemical chronologies were used to improve our understanding of physiological and movement histories of snapper populations in southern Australia. Our results highlight the significant influence of both intrinsic and extrinsic factors on chemical incorporation into otoliths, with implications for the future application of otolith chemistry for wild snapper populations.

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Muddy waters: An assessment of the suitability of zygocardiac ossicles for direct age estimation in the Giant mud crab *Scylla serrata*

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A fundamental characteristic of calcified structures commonly used for direct age estimation in animals is that new material is accreted cumulatively and preserved across ontogeny, thus allowing growth marks to be reliably observed and counted. Direct age estimation in crustaceans has been problematic due to molting of calcified structures across ontogeny; however, recent studies suggest that gastric ossicle tissue is retained through molts and can be used for age estimation. We evaluate the use of sectioned gastric ossicles for direct aging of the Giant mud crab *Scylla serrata*. Sectioned zygocardiac ossicles from crabs collected in northern Australia are analysed to determine: (1) whether putative annual age estimates can be reliably reproduced; (2) if age estimates are compatible with previous information; and (3) if ossicle growth is cumulative across ontogeny. Our analyses show that readability of putative annual increments in sectioned ossicles is poor and age estimates imprecise in comparison to fish otolith studies. Age-at-size estimates are broadly compatible with previous mark-recapture data from the same regions. However, analyses of ossicle growth morphology suggest that the zygocardiac ossicles are either shed or extensively reworked during ontogeny, thus casting doubt on the utility of gastric ossicles for direct age estimation in this species. We conclude that the ontogenetic growth morphology of structures used for crustacean aging needs to be carefully considered and that detailed information on the timing and frequency of increment formation—and at least some understanding of the underlying processes—is required before this method is widely adopted.

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Using visual tools to communicate science

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Visual communication tools are increasing in their availability and use in scientific disciplines. While technical research papers and classic journal formats will always have an important place in the scientific literature landscape, there is an increasing desire to make scientific knowledge, principles and practices more digestible for a broader audience. The application of animations for the communication of complex scientific principles and research outcomes to a wide range of audiences on a broad range of platforms (e.g. print, the web and social media) is a new and exciting frontier for science communication. We have combined creative thinking, with digital drawing tools and a cloud-based software to create an animated presentation on challenges and emerging trends in Commonwealth fisheries as a way to demonstrate the potential applications of some of the available tools.

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The Science Of Art: how science has influenced me as an artist.

Lindsay J Marshall[1]

1. Stick Figure Fish Illustration, Peregian Beach, QUEENSLAND, Australia

As a PhD, I have spent a large portion of my life being mentored and educated as a scientist and valuing that education. Science is not something you can teach yourself how to do. I consider myself to be scientifically minded and not 'artistic'. Therefore, I find it shocking to find myself working as a full-time illustrator. A discipline in which I am wholly self-taught. Today I reflect on the role that science plays in my work as an artist and how art can be created and enjoyed by anyone, with absolutely no training whatsoever.

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Driftwood fishes

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Over the last few years I've made a number of fish 'sculptures' using driftwood and jute twine. The saying "It's not about the destination, it's about the journey" is very apt. For me, it's about more than just having a visually interesting piece to hang on the wall at the end of the process. I love walking along the beach and collecting driftwood. I love the sorting, 'cleaning' and especially the feel and visual aesthetics of the wood. The pieces of driftwood and occasionally holdfasts and other flotsam are nearly always bound together with lashings or whippings (think Boy Scouts). The process takes considerable time, but can be quite 'meditative'.

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Schematic representations of fish interactions, habitat use and life cycle

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Conceptualisation of fish populations, fish behaviour and relevant processes forms the basis for appreciating fish, and is central to fisheries, ichthyology and management of aquatic ecosystems. Visual depiction of these concepts provide a means for communicating and refining individual and collective thinking about fish, fishes and aquatic realms. Working examples are used to discuss context, introduce functional principles of communicating visual information, and to address issues of artistic and scientific style. This includes specifically canvasing the needs of some practitioners to celebrate fish art and science-art personally or in a cultural sense. Narrow and broad target audiences are considered and attention is given to failures and successes in conveying concepts visually, with a view to promoting discussion around different ways to represent information in fixed 2-d and 3-d drawing space.

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When is art 'art' and when is it 'scientific illustration'?

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It can be difficult for scientists to venture into the realms of art as it seems frivolous and non-scientific. If it isn't realistic or part of a scientific paper, then it isn't scientific. To many scientists, scientific images represent a thing, not an idea. It can also be difficult for artists to venture into scientific illustration because it has no meaning, no soul, no message. For fish, especially those of economic importance, the trend towards illustrative accuracy makes the eighteenth century the crucial period of refinement. Some of the most artistic illustrations of fish appeared in Japan at this time, whereas western art's trajectory was towards photorealism. In this study, I examine the special place that fish have held in the history of art and how cultural representations of fish art are the equivalent of scientific illustration and that this dichotomy between what is art and what is scientific illustration is undeserved. Understanding human representation of fish is like a tour of art history—whether you fall into the 'it must be realistic' camp or 'it must be artistic' there are pathways for scientists. As Stephen Jay Gould said, "scientific illustration is not frills or summaries, they are foci for modes of thought".

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Silent invaders- ornamental fish as a leading invader of Australian freshwaters

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As an island nation, Australia has been well protected from invasions of freshwater fish that have plagued other parts of the world. With a suite of endemic fish species, 74 of these being threatened or endangered, invasion for some could push them to the brink. With an estimated population of 8.7 million pet fish and 1025 aquarium stores, Australia harbours a considerably large population of non-native species. Releases of a small number of these could lead to non-native ornamental species establishing and directly impacting our endemic fauna. Additionally, even the presence of a single non-native individual may also impact native fish via the spread of disease and parasites.

A 2010 Australian government report indicated a critical vulnerability in our protection against ornamental fish, stating: "there is little understanding of what species are traded in Australia. Similarly, there is little understanding of the level of prohibited or noxious fish bred and traded within the industry".

The presence of lists of permitted and inadmissible species do restrict the inflow of freshwater fish into Australia; however, our online monitoring on popular auction and sales groups has found unregulated and illegal trade of prohibited species, confirming government fears. Many species have also not been assessed for their invasive threat, and those that were initially identified as potentially harmful were deferred for further assessment due to their value to industries. Evidence of inadmissible species as pets is also acknowledged, furthering the need for an investigation of potential threats.

This lack of understanding of the threats from ornamental fish is a long-overdue issue in Australia the science community has failed to address. With their continued presence in natural waterways, such as peacock bass and parasite-infested goldfish, now is the time to start investigating and discerning what risk the pet fish population holds for our aquatic ecosystems.

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Evidence of naturalisation of the invasive jaguar cichlid (*Parachromis managuensis*) in Queensland, Australia.

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The introduction of non-native species poses a significant threat to the health of freshwater ecosystems in Australia. Impacts may include direct predation, competition for food and space, habitat modification, hybridisation, and the introduction and transmission of exotic diseases. It is well documented that ornamental keeping of exotic fish in Australia is a high-risk vector for accidental and deliberate release of fish. The jaguar cichlid or guapote tigre (*Parachromis managuensis*) is an aggressive piscivorous member of the cichlidae family. Native to the freshwater ecosystems of Central America, they prefer warm, highly eutrophic lakes and ponds with mud and silt benthic substrates. In recent times, an increase in demand and trade of jaguar cichlids has resulted in the species successfully establishing in many non-native ecosystems around the world. The history of the arrival of *P. managuensis* in Australia is uncertain, however likely occurred sometime in the early 1980s. Despite never being permitted for importation, ornamental populations persist to this day. In December 2014, the Department of Agriculture and Fisheries in Queensland was notified of a potential incursion of jaguar cichlids in a stormwater retention dam in the Pioneer River Catchment, Mackay, Queensland. Rotenone was applied to the dam in January 2015, and around 200 *P. managuensis* specimens at various life history stages were destroyed. Follow up surveys into mid-2015 did not detect the presence of any more jaguar cichlid in the dam or in nearby creeks. In September 2017, the Department was notified of a wild capture of a mature jaguar cichlid in Fursden Creek, 1.5km from the original incursion site. Follow up surveys in 2018/19 have also detected *P. managuensis* juveniles in Lagoon Creek, indicating successful establishment and naturalisation of the species in Australia for the first time.

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Testing the adaptive advantage of a threatened species over an invasive species using a stochastic population model

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Introduced species are a major contributor to the rapid decline of biodiversity in freshwater systems. Often eradication is not feasible, and management must focus on reducing the impacts on native wildlife. This requires an understanding of how native species are impacted but also how environmental characteristics influence the population dynamics of both the invasive and native species. In particular, it may be possible for managers to take advantage of advantageous life history traits that the native species possesses but the invader does not. The highly invasive fish, *Gambusia holbrooki*, has been implicated in the decline of many freshwater fish and amphibians. In south-eastern Australia, one of these is the threatened native fish, *Galaxiella pusilla*. However, the ability of *G. pusilla* to survive without surface water presents an opportunity to protect these fish, given *G. holbrooki* lack these adaptations. We developed a stochastic population model to explore the impact of *G. holbrooki* on *G. pusilla* and test the feasibility of both natural and management-induced drying to protect this species. Our results provide further support to recent studies that show that *G. holbrooki* are a serious threat to *G. pusilla* persistence, especially through impacts on larval survival. While persistence is much more likely in water bodies that frequently dry out, even optimal natural drying regimes may not be sufficient when impacts from *G. holbrooki* are high. However, management-induced drying may allow persistence of *G. pusilla* in water bodies inhabited by both species. Our results provide insights into how the effects of *G. holbrooki* can be mitigated for some native species, which is important given this species is perhaps the most pervasive invader of freshwater ecosystems. Using disturbance processes to exploit native species' adaptive advantages may also provide a tool for the management of invasive species more broadly.

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Characterisation and aetiology of Jelly-like gonad condition (JGC) in the common carp, *Cyprinus carpio* (L)

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This study examined a naturally occurring 'sterile' condition in the European carp population at Lake Sorell, Tasmania, Australia. The affected fish develop a 'Jelly-like' Gonad Condition (JGC). The condition was documented and characterised using multiple basic and applied methods ranging from histology to next generation total transcriptome profiling. Investigation of over 6000 fish indicated that it has a genetic aetiology, male specific and only found in mature carp. Morphological analysis suggested four distinguishable severity stages (stages 1-4). Additionally, histology and TUNEL assays of each severity stages revealed the early stages of JGC were marked by an abnormally high number of Sertoli cells (11 fold) coinciding with arrest of

spermatogenesis whereas late stages were marked by apoptotic cells. Extensive data analysis using 4,594 fish indicated a significant accelerated growth of JGC fish compared to their unaffected sibs. Hormonal analysis confirmed the level of circulating 11-Keto-testosterone (11-KT) in JGC fish was significantly (p>0/05) lower than in unaffected males, however, a feedback regulation of Luteinising hormone (LH) was observed. Analysis of milt samples indicated that, the quality and the quantity of the sperm cells dropped drastically with advancing severity. Transcriptome analyses revealed that 7,129 genes are differentially expressed between JGC and control testis, of which 40 genes were rationalised as a prime candidate. Further analysis revealed that many of the genes are novel and a total of 130 pathways are affected in JGC testis. Collectively data suggested that JGC fish are near sterile, particularly in the advanced conditions. It appears that this sterile condition is unique but can be valuable for applied (e.g. as Judas fish in management of feral populations and developing novel genetic control options) and basic (e.g. identifying sex-specific markers and as model for Sertoli cell carcinoma) research.

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Freshwater Biosecurity in Western Australia

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The introduction of non-native fish species into the environment is a major area of concern to aquatic management agencies around the world. Whilst Western Australia and Perth are considered to be relatively remote it is not immune to the introduction of non-native fish species through the release of angling, aquarium, aquaponics and aquaculture species. The Department of Primary Industries and Regional Development (DPIRD) in WA collects information on the distribution of non-native and native fish species via public reporting, surveys by institutions and consulting groups in addition to DPIRD survey work. Survey work undertaken by DPIRD since 2010 of permanent listed wetlands in the Perth Metropolitan Area identified that 81% of wetlands contained a non-native finfish species, conversely only 9% of wetlands contained a native freshwater finfish species. In addition to finfish, non-native invertebrates are also subject to being introduced. This survey determined that whilst 37% of wetlands contained a native freshwater invertebrate species almost as many again 32%, contained a non-native invertebrate species.

The introduction of non-native species is concentrated around areas of higher urban density, however, non-native species have also been introduced into remote areas of WA. Combining all the sources of information there have been 35 non-native fish species introduced or detected in WA freshwaters, with the majority of these in the southwest. Of the 35 species, 11 were part of active stocking programs, mostly for angling species, following the settlement of WA. More recently the majority are likely the result of aquarium fish releases.

Using a risk-based approach, DPIRD has undertaken targeted eradication activities on some of the more recent non-native fish species. The ongoing challenge is how to reduce the risk of fish releases into the future?

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Reproductive activity of freshwater fish differs spatially and temporally across the hydrological gradient of a wet-dry tropical river catchment

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Successful reproduction is the most important component of fish life cycles that contributes to population sizes and species persistence. Across many studies, successful reproduction of riverine fishes has been linked to variations in hydrology. The reproductive ecology of Australian freshwater fishes is relatively poorly understood, particularly for many species in wet-dry tropical northern Australia, and consequently there is little knowledge on how hydrology influences fish reproduction in this region. We undertook an intensive year-long larval fish sampling program in the Daly River and its tributaries to describe the variation in fish reproductive activity across spatial and temporal gradients in hydrology. Sampling occurred across the full range of hydrologic conditions, from base to peak flows, and in perennial to ephemeral flowing systems. Interspecific and temporal variation in larval abundances indicated that while some species (e.g. *Terapontids* and *Taxotes chatereus*) reproduced throughout the year, albeit at low levels, they did have a period of peak reproductive activity that was consistent across the catchment, which was when flow was high. However, for other species patterns of reproductive activity were more complex and differed across both the spatial and temporal gradient of hydrology. For example, the highest larval abundances of small bodied species (e.g. *Ambassis spp.*, *Craterocephalus spp.*, and *Melanotaenia spp.*) often occurred in dry periods in upstream reaches when flow was low or had ceased, while larval abundance of the same species in the perennial downstream reaches peaked during high flow periods. This study highlights key parts of the catchment and key elements of their respective hydrographs which are important for fish reproduction and larval occurrence. This knowledge will be important for management of future water and fisheries resources in the region, in the face of increasing interest in water resource development.

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River connectivity and fish migrations: Lessons learnt from regional scale E-flow assessments in Africa.

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Throughout Africa, water resource use is increasing with new dam developments and increases in other river connectivity impeding stressors. Good Integrated Water Resource Management practice in Africa includes the application of holistic E-Flow methods/framework that give adequate consideration to flow and non-flow stressors to describe the risk to socio-ecological endpoints in a holistic, multiple scenario context. This includes the protection of biodiversity and ecosystem processes of social and ecological importance that rely on river connectivity, including fish migrations. Fish have been included as socio-ecological indicators in E-flow case studies throughout Africa including; the Inner Niger River and Delta, the Nile River and numerous tributaries, in the Congo River Catchment and the Thukela and Orange-Vaal Rivers. These case studies have incorporated the use of fish as indicators of flows, water quality and habitat suitability. This includes the effects of, and requirements for river connectivity for migrations

that contribute to the biodiversity of systems, fisheries and associated human livelihoods, and important ecosystem processes such as energy transfers. The case studies demonstrated that there is sufficient empirical and solicited information to establish fish as ecological indicators that contributed to the E-flow assessments. Interestingly the requirements/preferences of different species/guilds associated with flow and habitat availability of the different ecosystems characterises the dynamism of ecological niches that fish occupy throughout the region. In these case studies fish have been established as important indicators of the socio-ecological consequences of altered flows and are being re-introduced as important monitoring components of the ecosystems throughout Africa.

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Flow-related spatial ecology of Murray cod: implications for environmental flow delivery

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Globally, river regulation alters the hydrological and hydraulic characteristics of riverine habitats, and threatens populations of many large-bodied, long-lived freshwater fishes. In the lower reaches of the River Murray, annual spring increases in discharge have been omitted from the flow regime, and low, stable flows predominate. In addition, the construction of weirs has substantially modified the hydraulic characteristics of this region. Reinstating 'ecologically important' components of a rivers natural flow regime is a contemporary management tool. Nevertheless, while an understanding of eco-hydrological relationships has advanced, the influence of riverine hydraulics (characteristics of flowing water) remains largely unknown, particularly for riverine fishes.

Throughout the Murray-Darling Basin, populations of Murray cod (*Maccullochella peelii*) are threatened by altered hydrological regimes and riverine hydraulics. Using fish tagged with radio transmitters and passive integrated transponder tags, we investigated aspects of the flow-related spatial ecology of Murray cod by comparing movement behaviour and habitat availability during two distinct hydrological periods: 1) low, stable spring flows and, 2) a spring flow pulse contained within the river channel. Habitat availability (i.e. water velocity and depth) differed between the two periods, predominately in the main river channel. No large-scale riverine movements of Murray cod were recorded during either low or spring pulse flows, but differences in movement behaviour were observed. Findings are discussed in relation to Murray cod conservation in light of contemporary river management, and the importance of integrating knowledge of eco-hydraulics into environmental flow strategies.

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Vagrant migrant or resident - an eel-life example

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Movement and residency times of longfin eels in estuaries, and rivers and other aquatic habitats in coastal catchments is generally understood and documented. The freshwater habitats of the land-locked catchments of Murray Darling Basin in south eastern Australia are not commonly associated with supporting populations of eels and when they are detected, it is generally as a single isolated occurrence and the record is usually dismissed as a vagrant or anomaly. As a result, anguilids are not considered when formulating specific management actions for protection and enhancement of native fish in these areas of the basin. A key knowledge gap is the route undertaken by eels detected in lowland rivers in land-locked catchments that are isolated by distance, waterway connectivity and physical topography from their original point of entry into Australian freshwater habitats. A mature longfin eel captured in the Macquarie River near Warren, New South Wales was examined to determine age, sex, residency time in saltwater versus freshwater and most probable migratory pathway by otolith microchemistry analysis. This preliminary information can help inform specific management actions relevant to this species, including the revision of the conservation status and adjustment of current bag and possession limits in western flowing rivers for these extremely rare and vulnerable long-term residents.

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Latitudinal variation in age-length relationships of golden perch within the Murray-Darling Basin

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Fish age-length information underpins the determination of growth rates and the formulation of fisheries management interventions. To avoid excessive destruction of fish for otolith aging, it is typical to use a relatively small sample to develop an age-length key (ALK) or a von Bertalanffy growth function (VBGF) to estimate age from length for the broader population. Accurate ALKs and VBGFs depend on sourcing the aged sample from the same locations as the broader population, and ideally covering a broad geographic region within a species' range. Using a sample of 856 golden perch (*Macquaria ambigua*) collected from 14 rivers throughout the Murray-Darling Basin, Australia, we modelled ALKs and VBGFs for fish from northern and southern basin regions. ALKs and VBGFs differed between regions. Dissimilarity was driven by the shorter life span (maximum age of 15 v. 24) and reduced length (maximum total length of 502 v. 549 mm) of northern compared to southern golden perch. Our results highlight the importance of understanding fish age-length structures that account for geographical variations in fish growth to accurately estimate age from length and to design and evaluate fisheries management interventions.

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Shedding light on the neuroanatomical organisation of the olfactory system in a shark (*Chiloscyllium punctatum*) compared to a teleost (*Carassius auratus*)

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The olfactory system of elasmobranchs remains understudied compared to other sensory systems, despite the common understanding that elasmobranchs have acute olfactory abilities. Although there is evidence to support that the size of sensory brain areas reflects their relative importance, olfactory inputs to the brain have not been quantified in any fish species. Here, we present a comprehensive study of the olfactory system of the brownbanded bamboo shark, *Chiloscyllium punctatum*, and the common goldfish, *Carassius auratus*, using bioimaging, electron microscopy and immunohistochemistry. An emerging bioimaging technique (diceCT) was used to accurately assess the relative volume of the olfactory bulbs in both species. Primary olfactory axons within the olfactory nerves and secondary olfactory axons within the olfactory tracts were quantified using transmission electron microscopy, to estimate the convergence ratio of primary to secondary inputs (input to the olfactory bulb compared to the input to the telencephalon) as a proxy for sensitivity. The type, relative abundance and distribution of olfactory receptor neurons (ORNs) in the olfactory mucosa of *C. punctatum* were assessed using immunohistochemistry. The relative volume of the olfactory bulbs was 2.5 times larger, and the convergence ratio of inputs was 10 times higher in *C. punctatum* than in *C. auratus*. ORN types identified in other fish olfactory systems were present in *C. punctatum*. The abundance of some ORN types were significantly higher than others and there was a degree of differential distribution across the olfactory rosette. Overall, our findings suggest that *C. punctatum* possesses a higher sensitivity than *C. auratus*, that olfactory bulb size is correlated with a higher number of inputs, and these olfactory inputs are functionally segregated. Such neuroanatomical comparisons are fundamental to improving our understanding of the evolution of the olfactory system in early vertebrates and the neural basis of olfactory abilities in both cartilaginous and bony fishes.

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Microplastics in seafood - a comparison between Australia and Fiji

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Plastic pollution is a huge worldwide environmental issue. Plastic objects enter the ocean and are broken down into smaller pieces, while waste water and runoff also carry microplastics (plastics <5mm) into the ocean. The structure and size of these plastics mean they have the ability to take up toxic compounds from within seawater and are often mistaken for food by marine organisms. Plastic has been found in many hundred different species of marine wildlife, but little research has examined seafood sold for human consumption in the southern hemisphere. We assessed the abundance and type of microplastics found in popular fish in Australia and Fiji. Fish from four species (goatfish, sea mullet, humpback red snapper and coral trout) were obtained from fish markets in Fiji and Queensland. They were dissected, the gastrointestinal tract digested in 10% KOH and the amount and type of microplastics identified under a microscope. Initial results showed that over 50% of sampled fish in Fiji have ingested at least one piece of microplastic with all species sampled containing plastics. On average, the fish in Fiji had 1.24 pieces of microplastic in their stomachs, with the maximum amount found in one individual being 10 pieces. Our results suggest that fish are consuming microplastics which may have implications for their health, and future longevity of certain important economic fishery species.

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Weedy seadragon demography through citizen science

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The weedy seadragon (*Phyllopteryx taeniolatus*) is an iconic, charismatic species which is protected yet thought to be in decline in SE Australia. It was listed as IUCN Near threatened, now downgraded to Least Concern, but our long-term censuses plus diver reports indicate widespread declines in the last two decades from popular dive sites. Our project engages scientists, conservationists, divers and the wider community to collect data on local populations, photographs for identification of individuals, tissue for genetic analysis. Here, we report on our latest data regarding spatial and temporal differences in abundance and growth of weedy seadragons, and how these may relate to changes in habitat.

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The Native Fish Management and Recovery Strategy

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As part of the response to the fish mortality events that occurred in the lower Darling River, and other parts of the Murray-Darling Basin during the 2018-19 summer, the Minister for Agriculture and Water Resources announced $5 million of joint government (state and Commonwealth) money

towards the development of a Native Fish Management and Recovery Strategy. Development of the Strategy, and its implementation, rely on robust multi-disciplinary scientific input as well as the need to recognise, complement and leverage current native fish recovery initiatives and capacity. Ensuring genuine community engagement and ownership is also fundamental to the Strategy's development and future success. Here we discuss progress with respect to the Strategy, including the development process and principles, stakeholder engagement framework, governance, key challenges and opportunities.

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Ngā Kaitiaki o Ngā Wai Māori: Caretakers of freshwaters - a pathway to return the essence of life to our waterways

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Tuna (*freshwater eels*) are an important taonga (*treasured, prized*) species in the Mangakāhia and Wairua River catchments. Many whānau (*families*) harvest tuna from the catchment as part of their regular dietary intake, as well as for hui (*meetings*) and tangi (*funerals*). In addition to concerns regarding local land use practices and the associated effects on water quality and instream fisheries habitat, tangata whenua (*people of the land*) are very concerned about the reduced availability of tuna.

In light of these concerns, in 2012 a hapū collective was formed called Ngā Kaitiaki o Ngā Wai Māori, representing Ngāti Hine, Te Parawhau, Te Kahu o Torongare, Te Uri-ro-roi, Ngāti Hau and Te Ore Wai. This collective has developed a strategic plan that expresses their goals, key actions and timeframes to address the poor state of their waterways. Key actions that aim to improve the health and wellbeing of tuna populations are specifically highlighted in this plan, including Goal 9: Manaaki Tuna and Goal 10: Tuna Housing, which include: Three annual elver transfer seasons completed; Monitoring of tuna transfers undertaken; Tuna friendly fish passage options implemented at the Hikurangi Flood Scheme and Wairua Hydro Dam; Strategies for assessment and management of tuna during and following flood events; Tuna housing options explored made ready and set in place in key waterways; and Evaluation of the benefits of tuna housing in overall tuna management.

Since 2012 Ngā Kaitiaki o Ngā Wai Māori have been working with a large number of agencies, hydro companies, land owners and research providers to achieve their goals. The leadership, communication pathways, and collaborations facilitated by Ngā Kaitiaki o Ngā Wai Māori have been critical to the implementation of restoration actions that will ensure that tuna populations in the Mangakāhia and Wairua River catchments are available for future generations.

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Biological and Genetic Controls of Tilapia

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Mozambique tilapia (*Oreochromis mossambicus*), listed in the top 100 of the world's worst invasive species (Lowe et al, 2000), have the ability to cause severe impacts to freshwater ecosystems primarily through competitive displacement of native species and habitat alteration. This alteration to natural ecosystems threatens both commercial and recreational fishing and tourism industries. Both *O. mossambicus* and the lesser known spotted tilapia (*Tilapia mariae*) have established significant populations within Queensland waters, and recent incursions into northern New South Wales are of great concern to managers. Eradication attempts are routinely attempted through the use of a combination of electrofishing and piscicide poisons, are rarely successful in open waterways, and are often unsuccessful for tilapia given their invasive nature. There is a lack of demonstrated broad-scale effective control mechanisms for tilapia and for invasive fishes in general. Biocontrol is likely to be a cost-effective and practical solution to managing invasive species because it does not require reapplication of chemicals or poisons, and once established should be self-sustaining. A combination of viral biocontrol and genetic technologies are emerging as the best applied technologies to incur a major decline in fish numbers, and in some cases even lead to complete eradication. We propose a systematic approach for investigating the use of a biocontrol agent and tilapia-specific genetic technologies, which could be combined as a broad-scale effective control measures for tilapia in Australia.

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Prepared for change? An assessment of the current state of knowledge to support climate adaptation for Australian fisheries

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Fisheries and marine ecosystems are challenged globally by climate change with subsequent biological and socio-ecological implications. Adaptation represents one pathway by which management agencies can seek to ensure sustainability of these resources for societal well-being, particularly when based on strong scientific evidence. Here, we examined the extent of primary scientific literature that is currently available to inform climate adaption initiatives for Australian fisheries. This is achieved via a systematic literature review for 99 harvested Australian marine species, aimed at identifying primary scientific articles that reported new knowledge of climate-driven biological changes and/or socio-ecological implications. We then assessed the quantity of scientific literature against estimated relative climate sensitivity scores for each species (from a previous study), and investigated factors that may influence relative research effort. We found that two-thirds of species had no peer-reviewed climate-related literature available, and that research effort among Australian fisheries species is most related to the number of commercial fish stocks per species, and commercial catch

weight. We also found that the south-east and western Australian regions had the most climate-related biological information to support climate adaptation in fisheries management. Nonetheless, although accumulating knowledge of the biological and socio-ecological implications of climate change is important, increasing knowledge alone is insufficient to maintain the productivity and profitability of Australian fisheries in light of projected climate impacts. We suggest that the further use of this knowledge to inform decision-making processes is essential to ensure that climate management adaptation options are fully explored, to allow sustainable and productive fisheries.

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Conservation implications of otolith geochemical discoveries for California's imperiled migratory fishes

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Effective conservation of fishes requires an accurate understanding of species' population dynamics, size-age structures, life-history strategies, spawning and rearing habitats, movement patterns, and the effects of human interventions. Though artificial tags (acoustic and other) yield valuable information for many species, adequate scaling of such approaches is often prohibitively difficult or expensive, and such studies are often limited to larger, abundant, or highly valuable fisheries targets. For small, endangered, and non-target species, or untagged portions of fished populations, other methods for reconstructing life history traits are needed. Otoliths (ear bones) and spines (calcified fin rays) exhibit internal features ("bands") that facilitate estimation of daily or annual ages and reconstruction of prior growth histories. Furthermore, chemical analysis of aged regions of otoliths provides temporally-resolved historical records of the ambient aquatic environment, thus allowing for the reconstruction of habitat use throughout the entire life of each individual. The Biogeochemistry and Fish Ecology Lab at UC Davis has used geochemical techniques (LA-ICP-MS) to analyze trace element concentrations and stable isotopes of Sr and O to address key questions about the life histories of several heavily-exploited and endangered fishes in California, USA. Here we summarise recent findings and their conservation implications regarding the cryptic collapse of wild-spawned salmon, the origins of salmonid pioneers, the diverse life histories of estuarine osmerid smelts, and the migratory behaviors of white sturgeon.

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How has a population of endangered Macquarie perch responded to reservoir enlargement?

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Ongoing drought and its threat to water security in the Australian Capital Territory resulted in the recommissioning and augmentation of Cotter Reservoir from ~4 GL to 78GL capacity. Of the four threatened species found within the Cotter River, Macquarie perch is at greatest risk to be impacted by reservoir enlargement. An ecological monitoring program commenced in 2010 to present day that centres on a series of management questions that aim to determine the impacts from construction, filling and operation of the enlarged Cotter Reservoir (ECR). Spawning and recruitment of young of year Macquarie perch was consistent prior to expansion, then there was little to no recruitment for a period of three years during the filling phase. Large instream barriers were the leading factor preventing Macquarie perch from entering the river to spawn, however spawning resumed once the reservoir reached full supply level. Adult Macquarie numbers and body condition increased in the early filling phase of the reservoir with the abundance of prey items available. Since 2016 there is a sign of decrease in adult Macquarie perch abundance which may be related to mortality or a reduction in capture efficiency (gear specification and/or fish behaviour) with the enlarged reservoir. Another explanation is a shadow effect from the three years of no recruitment resulting in reduced abundances of adults in recent years. The results from this monitoring program are an input to adaptive management programs implemented by the water utility, the ACT Government, the Parks and Conservation Service and other stakeholders to protect this population of Macquarie perch.

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Sargassum epifaunal communities vary with reef fish biomass and seascape setting within a fringing coral reef ecosystem

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Fishes that feed upon invertebrates play a key role in connecting the lower levels of productivity with higher trophic level predators in marine ecosystems. Here, we explore how the epifaunal communities in tropical macroalgal meadows may be linked to seascape position and the biomass of a range of invertivorous fishes known to occupy macroalgal meadows in the World Heritage Ningaloo fringing reef ecosystem. Within an overriding effect of seascape position, we found the biomass of some invertivorous fish families (Labridae, Lethrinidae, Mullidae and Serranidae) were linked to site-level variations in canopy epifauna, particularly gastropods and crustaceans. Foraging microhabitat preferences of these invertivorous fishes revealed those which positively target the *Sargassum* canopy, and are most likely the main consumers of epifaunal abundance and community structure. The implications for trophic flows from the primary and secondary production of tropical *Sargassum* meadows are discussed with respect to changes in macroalgal canopy over space and time.

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Historical biogeography of herbivorous coral reef fishes: the formation of an Atlantic fauna

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In this study, we describe the global biogeography of key herbivorous coral reef fish groups since their presumed origins, using data from both fossil and extant species. By applying the fossilized birth-death model, we built chronograms including a comprehensive sampling of extant species and all

the fossil occurrences described in Acanthuridae (surgeonfishes), Siganidae (rabbitfishes), and Scarini (parrotfishes). With the resulting chronograms, we built biogeographical models considering the geological changes in reef habitat availability since the ancient Tethys Sea. Finally, we used biogeographical stochastic mappings to trace the routes of colonization of the Atlantic Ocean by lineages in our focal taxa. We found that the Paleocene–Eocene was a period of significant lineage origination for surgeonfishes and rabbitfishes in the central Tethys Sea with the appearance of ancient genera. Most of these genera were probably extinct by the Eocene–Oligocene boundary as they do not correspond with modern taxa. Parrotfishes, however, originated in the early Oligocene, an epoch that corresponds with the geographic transition of the marine biodiversity hotspot. In all groups, extant genera had similar origin times and all expanded in the Miocene, mainly in the Indo-Pacific. In the Atlantic, only one parrotfish lineage with Tethyan ancestry appears to have survived. It subsequently gave rise to extant endemic genera (*Sparisoma* and *Cryptotomus*). The other extant lineages in the Atlantic all have Indo-Pacific origins and colonized more recently using different dispersal pathways. These results highlight the Atlantic herbivorous reef fish fauna as a conspicuous example of the importance of history in explaining the structure of extant marine fish assemblages.

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A phylogeny of Australian freshwater fishes

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The inclusion of phylogenetic data in ecological studies has grown markedly in recent years. Comprehensive species-level phylogenies are increasingly being used in a variety of applications, including in large scale studies of phylogenetic diversity, extinction risk distribution, speciation rates, and rates of trait evolution. However, large scale phylogenies of many groups are still lacking, and their construction is subject to a number of roadblocks. Traditional supertree methods are limited by quality and coverage of existing phylogenies, while large scale molecular supermatrix methods are hampered by incomplete and uneven taxon sampling in published data. Here, we present the first comprehensive phylogeny of Australian freshwater fishes. We include all formally recognised freshwater species plus a number of genetically distinct subpopulations, species awaiting formal description, and predominantly brackish water species for a total of 415 taxa. Molecular data for 320 taxa were compiled from Genbank and unpublished sources. These data cover 92% of genera and 93% of families found in Australian fresh and brackish waters. Phylogenetic inference was performed in IQtree using a partitioned multi-locus analysis of six mitochondrial and three nuclear genes. The resultant ML tree was timescaled using a penalised likelihood method and fossil calibration in treePL. A further 95 taxa for which no molecular data were available were then grafted into the tree using a statistical approach in conjunction with a taxonomic constraint. This dataset will facilitate the incorporation of phylogenetic data into macroecological studies of Australian freshwater fishes, enabling both correction for phylogenetic non-independence of data and studies of co-variation between phylogeny and ecology.

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Invasion genetics of common carp at the south east Queensland frontier

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Although Common carp (*Cyprinus carpio*) are considered among the worst invasive species globally, research efforts focused on the southern Queensland population have been lacking, resulting in a dearth of novel approaches to aquatic pest management. Interest in common carp within Australia has focused mostly on populations in the Murray-Darling Basin and its tributary riverways. The common carp of Australia originated from several sources of introduction, resulting in a genetically diverse population consisting of several genetic 'strains'. In particular, the Boolara strain has been implicated as being of significant management concern due to its seemingly innate potential for high proliferation of fish. While the current carp invasion front remains confined to Queensland's eight most southern catchments, assessment of climatic match indicates that further spread to neighbouring catchments is likely. In order to develop methods to enable early detection and response to new incursions, my PhD aims to genetically characterise Queensland's carp populations and investigate their detection and impacts on native community assemblage utilising eDNA. Carp populations will be sampled at both the established sites and the invasion front to determine the prevalence of each of the carp genetic strains in Queensland. Understanding the common features of the genomes of invasive fish will lead to the development of novel control measures for the state. In addition, I aim to use a strain-specific approach to survey the invasion front for site genetic characteristics key to successful invasion, as well as develop a whole community eDNA sampling protocol to survey the impacts of carp on native community assemblages. Together, these studies will provide a genetic evaluation of Queensland's carp populations, an assessment of their impacts on native communities, and a window into how best to monitor for future range expansions.

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Historic voyages, dusty tomes and shrivelled museum specimens: the search for the true identity of the Australian "common squid"

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A scientific communication challenge–to make traditional taxonomy of shrivelled museum specimens interesting. This paper embraces this seemingly insurmountable task, while unravelling the true identity of the Australian "common squid". The explosion of molecular techniques and data in recent times has led to a renaissance in taxonomy, with many formerly widely distributed species being split into closely related sibling or cryptic species on the basis of distinct molecular profiles, despite few discrete morphological differences. However, matching the new genotypes to existing scientific names can be extremely challenging. Some of the original type specimens (holotypes) held in museums are now deteriorated to the point of no recognition and most were typically fixed in formalin rendering DNA sequencing of their tissues currently impossible. Our study used a combination

of modern genetic methods and detailed body measurements to resolve the classification and distributions of the main coastal loliginid squids taken by fisheries in northeastern Australian waters. The results indicated that fisheries are currently harvesting five undescribed species of the *Uroteuthis* genus that were formerly classified as two widely distributed Asian species. While another two Australian loliginids were historically described and then later synonymised with these Asian species, their holotypes are now very deteriorated and it took considerable detective work through historic works and museum samples to try and reinstate the correct scientific name for one of the undescribed species. At the risk of provoking traditional taxonomists, we discuss the point at which historic descriptions and specimens might need to be abandoned as *nomina dubia*, and to start afresh.

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Contrasting patterns of population structure in sawsharks from southern Australian waters

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Sawsharks (family Pristiophoridae) are a group of demersal sharks that are characterised by a distinctive saw-like rostrum with a pair of long, whisker-like barbels on the ventral surface. In Australia, sawsharks are frequent by-catch in several commercial fisheries with the meat from these catches sold for human consumption. Although sawsharks have been caught since the early 1900s, knowledge of their biology is limited. One area in particular is how populations of sawsharks are structured.

Using mitochondrial DNA analysis, we examined the population structures of two sawshark species – the common (*Pristiophorus cirratus*) and southern (*P. nudipinnis*) sawshark – that are regularly caught by commercial fishing in the waters of southern Australia. Tissue samples of each species were collected from various locations throughout their ranges and the DNA extracted. Analysis of Cytochrome b and ND5 gene sequences indicated contrasting levels of population structure in these sawsharks, with *P. cirratus* consisting of two genetically distinct populations and *P. nudipinnis* consisting of a single population. Tests for population expansion over the sampling region also highlighted differences between the two species. *Pristiophorus nudipinnis* had a signature of population expansion whilst *P. cirratus* had an overall signature of stable population size, with evidence of population expansion in one mitochondrial lineage. It is hypothesised that the opening and closing of Bass Strait during glacial-interglacial cycles has played a role in shaping the population structure and expansion signatures observed in this study. These results greatly improve our knowledge of sawshark biology and will assist with the management of sawsharks in commercial fisheries.

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Queensland shark ID tool – a non-linear key for field identification

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A user friendly identification tool was developed to aid field identification of shark species encountered in Queensland's East Coast Inshore Fin Fish fishery and the Gulf of Carpentaria Inshore Fin Fish Fishery. The tool is suitable for a range of users (including monitoring staff, commercial fishers and compliance officers) in their usual operations, including remote locations. Correct species identification, although difficult, is important as it unpins accurate data collection for research, monitoring and harvest statistics, and in increasing confidence in the assessments derived from the data. Traditional dichotomous keys are cumbersome and require methodical examination of each feature in the sequence determined by the key and often need a high degree of technical knowledge. An agency wide innovation fund presented an opportunity to tackle this problem. Our aim was to produce a tool that facilitates fast and accurate shark species identification using a non-linear search process that uses simple images to categorise features. Using existing publications of species descriptions, a spreadsheet of 160 features and 129 taxa was produced. Lucid3.6 Builder was used to create a key for use on a personal computer or website. The tool is also currently being considered for conversion into an App for added mobility. Obvious characteristics are used to quickly reduce the list of possible species. Some shark species, particularly within the Whaler family are similar in appearance, and on some occasions it may not be possible to identify the species level with this key, based on the observable characteristics. This tool will however, allow users to produce a short list of potential species, and guide users to what additional features they can examine to help isolate the species.

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Using parasites to solve the enigmatic movements and population structure of marlin.

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Marlin are keystone predators that play important regulatory roles in the ecosystems they occupy. They are also one of the most iconic and important fish species to recreational and game fishing globally. However, both the ecosystem functions they provide and their value to fishing are dependent on the health of their populations. Managing marlin fisheries is often difficult as their cross-continental movements and population structures are poorly understood. This lack of understanding is largely attributed to the difficulty of tracking them, and marlin have one of the lowest tag retrieval rates of any fish. Marlin house an overlooked source of spatial and behavioural information: parasites. Parasites have limited distributions, and those found on fish can be considered records of the movements of that fish through different parasites ranges. Parasites were collected off marlin brought in to weigh at game fishing tournaments across NSW. The composition and size of the parasitic communities were assessed to determine the geographical regions where they infected the fish and for how long they have inhabited the fish. Isotopic analysis ($\delta^{14}C$, $\delta^{15}N$, $\delta^{34}S$) of both fish tissue and the parasites was also assessed to determine dietary aspects for both host and parasites. Results from this research will improve our capacity to understand and therefore manage marlin by using the parasites that live on them.

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Has reservoir enlargement changed the predator prey dynamics between an introduced salmonid predator and a threatened Perichthyid?

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Introduced salmonids are among the most destructive invasive fish globally. Brown trout are especially voracious predators, and have been linked to the decline of many fish and other aquatic species. Cotter Reservoir, a water supply reservoir in the Australian Capital Territory, was enlarged in 2013 to secure domestic water supply for the city of Canberra. Two salmonid species inhabit the Cotter Reservoir and Cotter River upstream, and have been shown to predate upon resident threatened fish species historically. The enlargement of Cotter Reservoir has seen a shift in the trout community within the reservoir, and also the commencement of predation by Brown trout on an endemic population of the endangered Macquarie perch. Brown trout abundances have boomed since reservoir enlargement. The resurgence in brown trout abundance is likely to have been fuelled by the breaking of the Millennium Drought, the increase in prey fish species from an expansion of space and food resources during the filling of the enlarged reservoir, and an increase in thermal refugia from increases in water volume and mechanical destratification of the reservoir. This paper explores the issue of increased brown trout abundance and describes the first confirmed incidence of predation of Macquarie perch by trout in the catchment - one of very few documented instances.

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The rise and fall of the Hazelwood pondage barra fishery. How the changing fate of coal-fired power generation affects tropical fish in a temperate environment

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In 2016 a barramundi fishery was successfully created in the Hazelwood power station cooling pondage. However, the unexpected early closure of the power station in March 2017 resulted in the loss of the fishery.

Power station cooling pondages have been used globally to create sport fisheries for warmwater species. The Hazelwood pondage was considered an ideal for creating a barramundi fishery in southern Australia to provide an opportunity for angles within a short drive of Melbourne without the expensive of travelling to northern Australia.

By August 2016, 6,800 (30 cm) farmed barramundi were released into the pondage. The fishery was opened 9 December 2016 as a ballot fishery. Around 26,000 registrations were received from anglers wishing to fish by boat. Permits were initially issued for up to 25 boats per day while fishing from the shore was open to anglers with a valid recreational angling licence. Following announcement of the closure of the power station the ballot system was removed to provide increased angling opportunities before the fishery declined.

Barramundi growth rates were exceptional with fish averaging 4.1 kg (+6.8 kg) and 63 cm (+87 cm) after 9 months, rivalling rates observed in northern Australia. This was attributed an abundance of prey (introduced cichlids), absence of competitors and optimal temperatures.

The fishery attracted over 5,000 anglers in four months, contributing $700,000 to the local economy.

The power station closed on 31 March 2017, reflecting a global trend away from coal towards low-carbon and renewable energy. Following the closure, water temperature declined rapidly from 30^{o}C to <15^{o}C in 1.5 months. To avoid a mass fish mortalities electrofishing was undertaken to capture as many fish as possible, which were euthanised. Most cichlids perished by June. Some barramundi were observed in the summer of 2018, but none have been reported since.

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The IMOS Larval Fish Monitoring Program – A valuable open access database to assess the future health of our oceans

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Seasonality and phenology of larval fish in Australian waters is not well explored. This project aims to understand future changes of fish distribution and phenology through the use of historical larval fish data and continued monitoring at a macro-scale. Larval fish are sampled monthly at five IMOS moorings around Australia including North Stradbroke Island (Brisbane), Port Hacking (Sydney), Maria Island (Hobart), Kangaroo Island (Adelaide) and Rottnest Island (Perth), and combined with sporadic research voyages. These samples are then sorted and identified into 218 standard taxa to quantify larval fish abundance and distribution. Results of this work have already produced a baseline dataset from subtropical and temperate waters of Australia (Smith et al. 2018). There is already evidence of blending latitudinal gradients by the East Australian Current. We will continue to deliver quality controlled data on the larval fish assemblages to the AODN in a timely fashion for use by the Australian research community. Ethanol preserved samples are also being collected for future DNA barcoding so we can ground-truth molecular techniques and better combine strengths of molecular and microscopy techniques in the future. Overall, the IMOS Larval Fish Monitoring Program will produce a valuable open access database, providing a fisheries-independent signal of reproduction, health and climate change, in relation to zooplankton and pelagic microbial diversity.

Boat moorings alter seascapes with consequences for fish communities; is there a solution?

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Boat moorings are common artificial structures ubiquitous with shallow embayments in urbanised estuaries. Traditional swing moorings consist of a heavy chain that scours the sediment as the attached boat moves at the surface, which reduces seagrass density and prevents regeneration. Impacts of swing moorings on seagrass are well-documented, but until recently little was known of their effects on fish. Here, we used underwater video and photography to understand the effects of boat moorings on fish communities and whether the implementation of less damaging seagrass friendly moorings (SFMs) benefit fish. Initially, we surveyed 4 mooring locations in Sydney Harbour to determine whether the abundance and feeding behaviour of fish communities differed at varying distances from the nearest mooring. At Manly Cove, where remnant seagrass meadows still persist, SFMs have been present since 2009. We mapped seagrass density at this location and later surveyed the fish communities and their behaviour in relation to a) seagrass, b) the identity of the nearest mooring, and c) whether the sampling point was within the impact area of the mooring (5 m). This allowed us to contrast the area of high disturbance (based on swing moorings) between mooring designs to understand whether engineering solutions, designed to benefit seagrass, have wider ecological benefits.