

Integrating socio-economic dimensions into ecological research and management frameworks

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Fisheries research, assessment and management is increasingly challenged by a need to broaden the previously narrow biological focus through consideration of ecosystem and habitat protection, biodiversity conservation, economic targets and social outcomes to support decision-making for sustainable management. These multiple objectives are further complicated by the need to account for the impacts of global climate change. In this talk I provide an overview of some modelling and related tools that are being used to address the increasing complexity and global connectedness of fisheries systems as well as account for changing targets and baselines. Examples are drawn from the Torres Strait tropical lobster and sea cucumber fisheries, Northern Prawn Fishery, forage fisheries and management of the crown of thorns starfish on the Great Barrier Reef. These examples highlight how management can effectively guide science to collectively address the key issues in fish and fisheries management. As an example of including socio-economic dimensions into ecological research and management frameworks, I provide an example of how socio-ecological models are being extended to represent dynamically the two-way feedbacks between ecological systems and linked socio-economic systems. In addition, I discuss the need to develop pre-tested strategies and adaptation options to prepare for climate change and respond appropriately to changes in the state and organisation of ecosystems, and their dependent societies. Finally, examples are provided of the challenges of facilitating communication with diverse stakeholders given that the success of future sustainability initiatives depends critically on effective communication.

Managing quota in a multi-species, multi-gear fishery in Shark Bay WA

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The Shark Bay Scallop and Shark Bay Crab Managed Fisheries form two commercially important fisheries operating in Shark Bay, WA. Each fishery is managed under separate legislated arrangements which provide the quota management framework for the sustainable harvest of each resource.

Noting the primary method of managing these fisheries is via quota, it was essential that a process was established that provided the Department with accurate weights of all crabs and scallop landed to effectively monitor quota and the manage each resource. Notwithstanding this, it was also important that the process was practical for industry and the Department to administer.

In developing a process, consideration was given to the unique challenges faced in these fisheries, given the long periods of time at sea, multi-species fishing (vessels are permitted to retain prawns, scallops and crabs), and the large quantities of product unloaded off the vessel at the end of each fishing period. In addition, being based out of a small regional town in northern WA presents its own operational challenges.

The Department has worked with industry to trial a voluntary quota reporting process for the past three years to overcome some of these challenges and assist in developing robust long-term arrangements.

Responding to changing demands in fisheries management, refocussing monitoring and assessment

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The increasing focus on ecosystem based fisheries management, public transparency and protected species mitigation is stretching limited fishery agency resources. This has required a rethink of commercial species' monitoring and assessment. The challenge is to do this in a cost-effective way that ensures ongoing fishery sustainability and general stakeholder acceptance. In the context of a multi-species fishery this leads to questions such as:

- how many stocks actually need target reference points?
- what are the consequences of adopting multi-year Total Allowable Catches?
- what risk assessment and management tools can be applied to byproduct and bycatch species to ensure sustainable fishing?
- in re-evaluating fishery data needs what are the consequential effects on data collection options (fishery independent surveys, observers and electronic monitoring)?

This presentation discusses recent experiences in the Commonwealth Southern and Eastern Scalefish and Shark Fishery as an example for possible responses to these questions.

Fish, fisheries and environmental assessment and management

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In NSW fish, fishing and fisheries are largely governed by the Fisheries Management Act, whilst environmental assessments are largely governed by the Environment, Planning and Assessment Act, with overarching evaluation by the Commonwealth's Environmental Protection and Biodiversity Conservation Act. Environmental assessments of fish in relation to human activities are closely guided by considerations of threatened species and key threatening processes. How does science contribute to this process and can the process then be used to focus or improve the science? There is an important role for fisheries scientists to assist in structuring of environmental assessments to aid fish and their habitats and the people who harvest fish for commerce or recreation. These matters are explored by reference to key legislation, review of types of impacts that can affect fish and fisheries (e.g. port development, mining, water management) and examples of how fish and fisheries are assessed for proposed human activities in NSW.

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Healthcheck for Australian Fisheries Sustainability

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Demonstration of fishery sustainability has expanded from a relatively narrow biological focus to one that includes a wide range of issues in response to environmental legislation, social factors, and demands from markets and consumers. The Healthcheck for Australian Fisheries Sustainability (Healthcheck) is a new initiative designed to be comprehensive with regard to ecological, economic, social and governance aspects, presenting available information about a fishery for easy access and use. Here we report on the framework development process, including engagement with fishery managers, environmental non-government organisations, and fishery participants. All participants emphasised the need for a broad sustainability assessment with timely reporting, easy availability, and wider coverage of seafood sustainability information than is currently accessible, and expressed the importance of trustworthy and transparent information. Differences were found when comparing sustainability issues generally reported and issues of main concern to stakeholders. Subsequent refinement of the Healthcheck has extended coverage into issues that are on the horizon for fishery reporting, but may soon be of interest to a wide range of stakeholders.

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Performance of Australian fisheries relative to target objectives

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An increasing number of fisheries within Australia are being managed under harvest strategies. These often aim to maintain stocks at or near a target reference point (TRP) and minimise the probability of stocks falling below a certain level or limit reference point (LRP). A number of sustainability classification schemes have been developed which designate stocks as sustainable if they are at or above the LRP. This can lead to a performance gap whereby some groups will consider a sustainable classification as sufficient evidence that a stock is well managed, even when the stock is not at or near levels targeted by management. Using the Status of Australian Fish Stocks, a national fisheries performance reporting platform, this study explores this 'performance gap', collating those species that contain an estimate of stock biomass relative to unfished biomass and comparing this against its assigned TRP. If an explicit TRP has not been defined, a proxy TRP will be assigned. This study will provide an assessment of Australian fisheries performance in terms of maintaining stocks at target levels rather than merely being sustainable.

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Applied science in the era of 'fake news': are we moving forward or backward?

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The job of the applied scientist is a tough one. Criticised by academia for research that doesn't consider the global conceptual model, hassled by management investors for trying to do research that does consider the global conceptual model – it's a constant battle for validation. Regardless, applied science, which straddles the divide between furthering ecological theory and progressing the real-world realities of solving complex on-ground problems to improve management outcomes, is becoming increasingly vital in a world where opinion means more than fact. Globally, there are increasing examples of robust science being ignored in favour of popular opinion. While disregard for science is not a new stance (i.e. the world is flat, climate change denial, anti-vaccine lobby) the recent peak in social scepticism and short-termism is flowing through politics, via management decisions,

to the role of science in decision-making. As such, researchers working on applied problems who possess the ability to articulate complex ideas to the community in a digestible way are increasingly needed to bridge the cultural gap and enable 'opinions' that are at least based on evidence. This conversation is just beginning. In this presentation, I provide a summary view on what applied science means for fish and fishery management in Australia in 2018, and how, as researchers and managers, we can set ourselves up to deliver evidence-based research and management outcomes in a changing world.

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Influence of river flows on small-scale movements of Golden perch and Murray cod in the Namoi River: implications for water sharing planning.

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Linkages between small scale movements (0-10km) and river flow was investigated for golden perch *Macquaria ambigua* and Murray cod *Maccullochella peelii peelii* in the Namoi River using acoustic telemetry. Movement was strongly seasonal for both species, being most prevalent during the spawning season (spring to early summer). Golden perch were typically sedentary over winter and undertook upstream movements in spring. Murray cod activity was highest in spring and lowest in summer. Murray cod were also observed to undertake frequent small-scale movements in response to small flow-pulses during winter, suggesting these flows may be of ecological importance to this species. Greater access of irrigators to supplementary flow events between July and October are currently being considered for inclusion in the revised Namoi River Water Sharing Plan. The frequent small-flow-pulse associated movements of Murray cod during these months emphasises the need to ensure that any increase in irrigator access does not significantly impact on the frequency, size and duration of small flow events.

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“Does anyone here speak water-ish?” – How the benefits of environmental flows get lost in translation.

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Research commissioned by the Victorian Environmental Water Holder (VEWH) in Australia has found strong evidence that the language and complexity of water management is excluding communities from understanding what environmental flows are and their benefits, including for fish. A statewide market research project has confirmed startling levels of misunderstanding that stem from impenetrable water language.

As the second driest continent on earth, Australia's use of water is a key matter of public interest which will only grow in importance as climate change progresses. Modelling now predicts that streamflows could reduce by around 50 per cent in some Victorian catchments by 2065. This has serious consequences for everyone - households, industry, agriculture, recreation, cultural values, native plants and wildlife. Scrutiny of the management and value of environmental watering is only expected to increase.

To help increase public acceptance of water for the environment, it will be essential to first increase levels of water literacy. This concept is likely to have broader relevance beyond the management of water for the environment. If we want to grow public and political interest and support for efforts to improve the health of our waterways and the fish communities that live in those waterways then we need to ensure we communicate via a shared language.

The VEWH aims to meet public need by improving the transparency around its decision-making and providing clearer, more accessible information about the rationale and benefits of environmental watering. To be successful, it argues, the water industry needs to break down potential verbal and intellectual barriers, simplify its management concepts and speak to people in language they understand.

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Friends with benefits when fish science met environmental water management

Heleena Bamford, Stuart Little

Planning and managing environmental water for native fish outcomes in the Murray-Darling Basin has come a long way over a short space of time. We used to celebrate the achievement of spawning in the River Murray, but now we seek system-wide recruitment outcomes. Environmental water holders and managers have undertaken a paradigm shift, moving from a simple local approach for a singular outcome, to a system-scale, population dynamics approach to water management. But how did this happen? It has taken time, the efforts of many scientists and water managers, and some key pieces of research and monitoring. We will reflect on the influential pieces of research, the important policy and management changes, and the major outcomes that have shaped this journey so far. We will also show how native fish knowledge is helping to communicate the benefits of water for the environment to a broader audience, and build support for water reform more broadly.

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Meta-population model to inform the management of a once widespread flow dependent freshwater fish.

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A 30-age class stochastic meta-population model was developed for silver perch, with 4 populations located along the main stem of the southern connected Murray-Darling Basin, including the Murray River and the Lower Darling River (below Menindee weir). The model accounts for survival, fecundity, and movement (immigration and emigration) in each population and includes the influence of flow and temperature on silver perch population dynamics. Estimates of age specific survival were derived from age-frequency data and fecundity was estimated from age-length-weight data combined with an established weight-fecundity relationship. Two 22 year flow and temperature data sets were assessed: 1) data from various gauges around the southern connected basin; and 2) an altered flow representing how environmental flows may have been allocated for the past 22 years. The silver perch dynamics response to the two flow and temperature data sets are presented and the implications for management.

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Recovery of threatened dwarf galaxias along Dandenong Creek, Melbourne

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The dwarf galaxias (*Galaxiella pusilla*) is a small bodied freshwater fish of national conservation significance from south-eastern Australia that typically occurs in slow flowing, well vegetated habitats such as wetlands, swamps billabongs and small streams. Across much of its range, including Melbourne, dwarf galaxias habitats have been progressively fragmented and degraded as agricultural and urban areas have intensified and expanded. The spread of invasive fish, particularly eastern gambusia (*Gambusia holbrooki*), is also likely to have contributed substantially to the decline of many dwarf galaxias populations.

We provide an update on a major dwarf galaxias recovery project along an 18km reach of Dandenong Creek, Melbourne. The project commenced in 2013 and involves creating or improving 20 inter-connected floodplain habitats, as well as breeding and reintroduction of genetically suitable fish stock from multiple wild populations across the greater Melbourne region. An overview of the project objectives, habitat designs, fish stocking program and ongoing monitoring will be given. Plans to reintroduce nationally threatened Yarra pygmy perch (*Nannoperca obscura*) into the same habitats will be discussed as well. We also highlight where research has directly informed the project and links to current research that is expected to inform recovery efforts in the future.

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Using behavioural information to inform conservation of the threatened dwarf galaxias

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Wetlands constructed to treat stormwater are often inhabited by animals that can suffer impairments. Such effects will be exacerbated if animals are caught in 'ecological traps' whereby they mistakenly prefer sites where their fitness is reduced. Traps can compromise population persistence, so assessing if the fitness of animals is lower at stormwater than natural wetlands, and if animals can avoid poor quality locations can guide management efforts.

We tested if the fitness (e.g. survival, development) of the threatened dwarf galaxias (*Galaxiella pusilla*) was lower at stormwater wetlands around Melbourne, and if so, whether fish avoid poor quality sites. We also examined the potential effects of the invasive mosquitofish (*Gambusia holbrooki*) across the life cycle of dwarf galaxias, and whether *G. pusilla* recognise this threat.

We found that *G. pusilla* are susceptible to ecological traps. Survival was lower at stormwater wetlands and fish suffered delayed ovarian maturation, and mosquitofish ate larvae and disrupted breeding. However, *G. pusilla* did not avoid water from stormwater wetlands or cues from *G. holbrooki*. We discuss our results in the context of how insights from animal behaviour can inform threatened species conservation in fragmented urban landscapes.

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Distinct behavioural responses of selected closely related New Zealand native galaxiids to progressive escapable hypoxia

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The New Zealand native galaxiid species inanga (*Galaxias maculatus*), banded kokopu (*Galaxias fasciatus*) and black mudfish (*Neochanna diversus*) are closely related, but exhibit different habitat preferences, with distinct oxygen regimes. Inanga prefer lowland open rivers and lakes, while banded kokopu usually live in heavily shaded pools of small tributaries and black mudfish primarily inhabit lowland swamps and wetlands. The capacity of each species to detect and respond to progressive, escapable hypoxia was studied using a choice chamber. Of the three species inanga were the most sensitive, actively avoiding mild hypoxic conditions (< 5.9 mg L⁻¹), while the avoidance threshold of banded kokopu was lower at < 2.5 mg L⁻¹ and black mudfish

demonstrated no avoidance of hypoxic water. In addition, species displayed specific behavioural responses to hypoxia. The frequency with which inanga switched between hypoxic and normoxic areas increased with more severe hypoxia. Banded kokopu increased the frequency of surface respiration and swimming speed, improving oxygen uptake through increased ventilation of oxygen-rich near-surface water. Black mudfish displayed no obvious change in behaviour to hypoxic conditions, indicating a pronounced hypoxia tolerance. These findings demonstrate species-specific hypoxia sensitivities and distinct behavioural strategies towards hypoxic environments.

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The effects of hypoxia on Australian freshwater fish species

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Persistent hypoxic conditions in aquatic systems are becoming more frequent worldwide, causing large-scale mortalities to aquatic fauna. Studies investigating hypoxia tolerance of fish are limited and tend to be focused on marine species and short-term exposure. There has been minimal effort to understand the implications of long-term exposure on fish and their ability to acclimate. Three native Australian freshwater fish species were exposed to normoxic and hypoxic conditions at different temperatures for between 7 days and 10 months, before being placed in individual respirometry chambers to measure a range of physiological responses including metabolic rate, hypoxia tolerance and acclimation ability. Hypoxia tolerance varied among species, but long-term exposure improved tolerance to hypoxia. While prior exposure to hypoxia may allow fish to cope with hypoxic conditions better in the long-term, acclimation time was inversely related to tolerance, suggesting that resistance to hypoxia might decrease as a function of exposure time. Our study fills a much-needed gap in understanding how freshwater species acclimate to hypoxia; in particular how exposure to prolonged periods of hypoxia and elevated temperatures affect organisms physiologically.

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Effects of temperature on habitat use and home range patterns of coral trout *Plectropomus leopardus* on the Great Barrier Reef Australia

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Physiological performance of marine fishes is highly sensitive to changes in temperature, such that spatial and temporal variation in ocean temperatures may have a marked impact on activity and behaviour. This study uses acoustic telemetry to examine variation in habitat use of coral trout (*Plectropomus leopardus*) among seasons and between locations in the northern versus southern sectors of the Great Barrier Reef, Australia. Spatial and temporal differences in habitat use were strongly linked to seasonal and latitudinal variation in temperature. The southern population typically had larger home ranges than the northern population, 0.29 km² compared to 0.23 km² respectively and space use decreased substantially during the summer time, particularly for the northern population. This study provides important information on the effects of increasing temperature on fine-scale movements and habitat use of wild stocks of coral trout. These data complement existing tank based studies, to better inform predictions about how *P. leopardus* populations and coral reef fisheries generally, might be impacted by sustained and ongoing global climate change.

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Mixed-species Shoaling as a Behavioural Mechanism Facilitating the Survival of Tropical Fishes in Temperate Regions

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Tropical fishes recruiting to temperate regions outside their native range (termed vagrants) provide an exciting opportunity to investigate behavioural interactions between tropical and temperate species and how these will be impacted by climate change. For gregarious vagrants, the formation of mixed-species shoals with native heterospecifics may provide benefits in terms of predation avoidance and foraging efficiency in novel temperate environments. Each year, small numbers of larval *Abudefduf vaigiensis* (Indo-Pacific Sergeant) are transported southwards from the coral sea, settling in sheltered embayment's on the temperate coast of south-eastern Australia. To evaluate the extent to which mixed-species shoaling behaviour facilitates the growth and survival of vagrant *A. vaigiensis*, I have conducted visual surveys and *in situ* behavioural observations along with laboratory-based shoal choice experiments. I have then modelled the influence of key factors, namely shoal composition, water temperature and habitat type, on shoaling behaviour. Results revealed that 68% of shoals contained multiple species and *A. vaigiensis* displayed preference larger mixed-species shoals when under predation threat and when in exposed habitats. These findings provide broad support for the importance of mixed-species shoaling behaviour and exemplify how novel behavioural interactions between tropical and temperate species may structure the redistribution of fishes with climate change.

Understanding the effects of river flows on population connectivity and genetic viability of Australian freshwater fish species

Katherine Harrison, Zeb Tonkin, Wayne Koster, Jason Thiem, Brenton Zampatti, Nick Murphy, Jarod Lyon

Understanding the links between river flows and the health of native freshwater fish populations is critical for efficient and effective delivery of environmental water. Currently the status of freshwater fish populations is assessed primarily by examining changes in abundance and population age structure. While this data can provide some information on short-term population responses to environmental flows, critical processes such as population connectivity and genetic viability can be poorly represented. Genomic data, which require less-intensive field sampling to obtain than population demographic data, can improve information about these critical processes. Our study uses highly resolving genomic methods to explore the effects of river flow conditions on connectivity and genetic health of two Australian freshwater fish species with contrasting life histories: golden perch and Australian smelt. We demonstrate the value of genomic tools for understanding the spatial extent of population connectivity across the southern Murray-Darling Basin and the role of environment, including river flows, in shaping processes critical for long-term persistence of native fish populations.

Live fast, die young? Mixed effects modelling reveals limited support for a pace-of-life syndrome in trout

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Phenotypic correlations and trade-offs amongst traits play a vital role in determining an individual's fitness. The pace-of-life syndrome (POLS) posits that behavioural, physiological and life-history traits are correlated, such that selection on one or more of these traits will drive coevolution in the others. However, the strength of these correlations and associated fitness implications, remains largely unexplored. Individual phenotypes are comprised of both within- and among-individual variance, a factor that is often overlooked when examining correlated traits. I tested for a pace-of-life syndrome linking growth rates, metabolic and behavioural traits in brown trout fry *Salmo trutta*. Using mixed effects models I partitioned phenotypic variance into its within- and among-individual components, using univariate models to test for repeatabilities in traits and multivariate models to quantify correlations between traits. Most traits exhibited significant repeatability but correlations among traits were only present within and not among individuals. My results therefore do not provide support to the POLS hypothesis. Rather they, suggest that individual pace-of-life may be more nuanced, dependent on environmental or developmental contexts. My study provides a framework from which to continue to examine correlated traits, highlighting important aspect of the statistical methods required as well as encouraging avenues of further research.

Ecology matters: pace-of-life syndrome differs between two populations of eastern mosquitofish with divergent life history

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The pace-of-life syndrome (POLS) hypothesis predicts variation in behaviour and physiology among individuals to be associated with variation in life history. Thus, individuals with "fast" POLS should grow faster, exhibit higher metabolism, be more risk prone, but die earlier than "slow" ones. Empirical support is nevertheless mixed and modelling studies recently suggested POLS to vary along selection gradients. Therefore, including ecological variation when testing POLS is urgently needed to understand whether POLS is a fixed or a variable construct. Here, we tested POLS predictions between and within two fish populations originating from different ecological conditions. We observed opposing life histories between populations, characterized by diverse investments in growth, fecundity, and functional morphology under identical laboratory conditions. Yet, a slower life history was, on average, associated with boldness, high activity, and increased metabolic rates. Within populations, among-individual differences in boldness, activity, standard metabolism, and size-at-age were repeatable over ontogeny, indicating that individuals differed consistently from each other. However, correlation structures among POLS traits were not consistent between populations, with POLS observed in the slow-growing but not in the fast-growing population. Our results suggest that POLS traits can evolve independently from one another and that their coevolution depends upon specific ecological processes.

Niche construction by a farming fish & the natural selection of domestication

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While farming is often considered an inherently human activity, many animals also exhibit complex farming behaviours. One of the best-known examples occurs on coral reefs, where territorial damselfish actively maintain and protect an area of turf algae, increasing its dietary quality. In the Caribbean, swarms of mysid shrimp also associate with these damselfish territories, however, the exact nature of this second relationship remains unknown. Here, we show that mysid swarms receive a clear protective benefit from this association, experiencing significantly reduced rates of predation when damselfish are present. However, associating with mysid swarms comes at a cost to damselfish, increasing the time spent defending territory and reducing feeding rates. Despite this, mysid-associated fish are in significantly better condition than fish without associated swarms. This appears to reflect the higher quality turf found within mysid-associated territories, likely due to the high levels of additional nutrients that mysid swarms contribute to the immediate area. In this way, by protecting mysids within their territory, damselfish receive a consistent source of 'fertilizer' for their crops. This study represents the first evidence of integrated multi-trophic farming in a fish.

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Life-history, ecology and demographics of the spiny dogfish (*Squalus acanthias*) in an environmentally impacted estuarine environment

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The life-history characteristics and behaviour of a species can be affected by their environment; and understanding these relationships is necessary to effectively inform management. *Squalus acanthias* is a common and abundant shark species in the temperate shelf waters of the world. It is locally abundant in Macquarie Harbour, a large embayment in western Tasmania. During the past decade, declines in dissolved oxygen and benthic conditions have occurred in Macquarie Harbour, associated in part to impacts of large-scale marine farming, raising serious concerns about the environmental health of the system. In this study we examined several aspects of the spatial ecology, reproduction, diet, growth and demographics of this *S. acanthias* population. Several traits were distinct from what is typical of the species elsewhere. Namely that the population appears demographically isolated and range restricted to the harbour, their diet is heavily reliant on spillover feed from aquaculture, and their reproductive output appears to be severely compromised. These findings are significant, as they highlight the important and complex ecological role of the species in the ecosystem, but also suggest that under current conditions they are unlikely to thrive and will have a severely limited ability to cope with further external pressures.

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Reforming the South Australian Marine Scalefish Fishery

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The South Australian Marine Scalefish Fishery has recently undergone a strategic review with the principal aim of restructuring the fishery in order to ensure its long-term sustainability and economic viability. Like many coastal inshore fisheries around Australia, it faces numerous challenges, including fish stock decline, economic viability problems and tensions between commercial and recreational fishing sectors over shared access to fish stocks. The heterogeneous mixture of participants, fishing devices, licence conditions and regulations associated with this fishery makes the task of administering and managing it extremely challenging. Industry and government have worked collaboratively to address the inherent complexities of the fishery. Strategic management options developed include regionalisation (or zoning the fishery), rationalisation (removing up to 30% of licences) and introducing a contemporary management framework including quotas that will provide incentives for investment in the fishery and a mechanism to facilitate continual autonomous adjustment. This presentation explores the processes undertaken to date, the proposed reforms developed, and the methods to disentangle and understand the fleet dynamics of this extremely complex fishery, and examine the future structure and viability of the fishery from a resource sustainability, economic and social perspectives.

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Best practice guidelines for Australian fisheries management agencies

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We have standards for sustainable seafood products – but what is best practice for agencies that manage these resources? Guidelines for marine fishery management agencies is consistent with broader directions in government policy and expectations of stakeholders and the broader community. Over a two-year period a multi-agency project team developed draft Guidelines, now out for general consultation and review. Use of these Guidelines offers a range of benefits for Fishery Agencies including to demonstrate best practice and support continuous improvement, inform strategic planning, structural and legislative reform, harmonise or coordinate functions between jurisdictions, and build credibility and transparency with external parties, such as media and general public. The Guidelines can assist with reporting and justification of management costs including highlighting efficiencies and cost savings, development of co-management approaches by clearly describing key functions for each partner,

and support external certification processes. Potential fishery and community benefits include increased support for fisheries as a result of management transparency and increased community understanding of how fisheries operate. Market benefits might include information provision for consumer-facing seafood guides and seafood sourcing schemes. Finally, there may be International benefits including benchmarking Australian management agencies relative to international management approaches and performance.

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The role of partially protected areas as a conservation and management tool

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Management of fisheries is a vital component of marine conservation in Australia and globally. Effective fisheries management strategies require the interests of multiple stakeholders to be balanced against important conservation outcomes. This study investigates the potential for partially protected zones to contribute to this balance, and provide a “conservation middle ground”. Conservation Park Zones (CPZs) are zones within the Great Barrier Reef Marine Park where partial protection is provided through restrictions on the type and amount of fishing gear permitted. Using a combination of survey techniques, we conducted surveys of fish assemblages in CPZs, as well no-take marine reserves, and open fishing zones for comparison. Here, we examine trends in fish assemblages in CPZs, and assess their utility as a fisheries and conservation management tool. Focus is given to key fisheries targets, and the ability of CPZs to protect key ecological processes such as predation and herbivory. Our initial findings suggest that partially protected zones have the potential to be an effective compromise between no-take marine reserves and open fishing areas. Ongoing research in this field will provide much needed insight into the ability for partially protected areas to enable conservation outcomes and support fisheries management on coral reefs.

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Evaluating fishery management strategies with the inclusion of a marine closure.

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Marine closures are commonly used as a fishery and biodiversity conservation management tool. The consequent spatial structuring and reduction of data to inform assessments of status is known to bias assessments.

Both data-rich and data-poor based management strategies were evaluated for their ability to attain biomass targets and have reasonable biomass risk profiles (the probability of the biomass falling below a limit reference point). Our results suggest that full quantitative assessments generally performed well in terms of meeting target biomass levels for the open area. In contrast, data-poor management strategies perform less well with increased biomass risk.

If managers choose a stock-wide target, then the open area biomass target can be less than the stock-wide target, due to the protection of stock within the closure. A stock-wide biomass target strategy also tends to maintain catches irrespective of mixing level. Alternatively, a harvest strategy based on a biomass target for the open area alone led to higher catch rates and stock-wide biomass for a particular mixing rate, but with potentially less annual catch than a strategy based on maintaining stock-wide biomass.

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Adapting to challenges in a Western Australian abalone fishery

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The commercially and recreationally important Perth Metropolitan Roe's Abalone Fishery is one of the only remaining sustainable abalone stocks on the door step of a capital city in the world. The fishery's location provides significant commercial and recreational advantages over other Roe's abalone fisheries in Western Australia, often presenting significant management challenges.

In 2011, a marine heatwave caused significant mortality in the fishery resulting in record low spawning biomass and recruitment. This led to the development of and implementation of additional performance indicators and harvest control rules to recover the fishery based around a total allowable catch.

Since 2012, five recreational fishers have died while recreational fishing for abalone in WA. This led to the need to change management arrangements to improve fisher safety.

This presentation outlines the key challenges faced in both recovering the stock and improving fisher safety and the conciliations required to find the appropriate medium.

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MSC certification as a driver for collaboration between science, management and industry – the WA experience.

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The Marine Stewardship Council (MSC) standard assess fisheries across three core principles: sustainable target stocks, environmental impacts below acceptable limits and effective management. Achievement and maintenance of an MSC certification across those principles requires commitment and cohesive efforts among often disjunct areas of science, management and industry at both institutional and individual levels.

Five Western Australian fisheries have been recently assessed for the first time under the MSC standard and have earned the right to use the ecolabel's "blue tick". Assessment was initiated through the State Government's third party certification scheme, whereby fisheries committed to achieving and maintaining the MSC standard had their assessment and first audit funded by the State.

The linkages and relationships forged through the assessment process and maintenance of condition milestones have facilitated a large number of ongoing initiatives with clear benefits to all three parties as well as the development of best practice fisheries management and a shared vision of sustainable, well managed fisheries.

This presentation will explore some of the challenges encountered throughout the certification process as well as how they are being addressed, and the structures which continue to facilitate the collaborative efforts to that end.

29

Integrating diverse data types to improve predictions of size-structured population dynamics

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Accurate predictions of population dynamics are critical to the management of natural resources and can be used to inform sustainable harvest policies, to control invasive species, and to guide conservation actions for threatened species. However, accurate predictions of population dynamics require extensive data, which are not always available. Recent statistical methods overcome data shortages by piecing together diverse data types in a single, "integrated" analysis. Integrated models make full use of available data and link different data types directly to the underlying ecological processes. We developed an integrated model to estimate size-dependent survival and fecundity of Murray cod (*Maccullochella peelii*) from a combination of size-abundance data, mark-recapture data, and individual growth trajectories. We used Hamiltonian Monte Carlo and the TensorFlow software library to generate fully Bayesian parameter estimates, typically assumed to be computationally prohibitive in large integrated models. The integrated model fitted observed size-abundance data closely and generated plausible estimates of vital rates, including fecundity estimates very similar to existing estimates in the literature. Our integrated modelling approach can be used to predict future size-abundance distributions and can be extended to include information on local environmental conditions, individual movement, and interspecific interactions.

30

Do fish respond to enhanced in-stream detritus? Using ecology to inform restoration

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In-stream habitat restoration generally focusses on providing large, expensive structures for large, adult fishes. Many of these projects fail to achieve their intended outcomes because they rely on a "build it and they will come" approach, which often ignores how fish will likely respond to restoration attempts. Here, we experimentally explore how native fish respond to in-channel habitat modification, and demonstrate the potential application of a novel, low-effort method of restoring fish populations. Pairs of wooden garden stakes were placed in a degraded, sand-affected stream, which effectively trapped passing detritus and locally increased detrital loads. Over the course of a year, we assessed the response of the fish community to this increase in detritus. Greater abundance of river blackfish, mountain galaxias and southern pygmy perch were recorded at sites with enhanced detritus. This positive response of fish, however, was contingent on the time of year, the life-stage of individuals, the age of the treatments and the broader stream habitat conditions. The complexity of our results highlights the importance of understanding the ecological constraints on a fish community before attempting to undertake restoration.

31

Fish and Flows: Developing objectives and targets for freshwater fish in NSW Long Term Water Plans

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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. Implementation of the Basin Plan provides the opportunity to improve flow regimes and contribute to the restoration of native fish populations. Nine Long Term Water Plans (LTWPs) are being developed for catchments across NSW, setting objectives for five, 10 and 20 years. The LTWPs will inform the annual decision making process and guide the management of water to maximise river and wetland health outcomes in the relevant catchment and the MDB. NSW DPI Fisheries used the latest management and scientific information to develop five different 'functional groups' of fish species identified based on shared life history characteristics and responses to flow. The Environmental Water Requirements (EWRs) to support these life history characteristics were then developed. Valley scale objectives and targets in LTWPs have a direct line of sight to the overarching basin scale outcomes and are ecologically relevant to the management and monitoring activities within the valley. It is anticipated that the implementation of these EWRs will contribute to the achievement of overarching Basin Plan outcomes and valley specific objectives and targets for native fish.

32

Looking for larvae in a stressed river system – is adding water enough?

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2. *Department of Environment and Science, Queensland Government, Brisbane, Queensland, Australia*

A common expectation of providing environmental water for fish in regulated rivers is that such flows will stimulate spawning and lead to juvenile recruitment. The Lower Balonne River network is regulated by a number of upstream dams including Beardmore Dam. Downstream of this are regulating structures that determine eventual flow paths. We ran a short-term study in the Lower Balonne river system to investigate temporal patterns of fish larval and zooplankton abundance in two tributary channels (Culgoa and Narran Rivers). Sampling occurred monthly from August 2017 to April 2018. Rain events lead to three stock and environmental releases from Beardmore Dam in this time resulting in two small pulses in the Culgoa River in October and December and a larger flow in both rivers between March and April. Larval abundance was extremely low for all potential species for the whole study apart from small numbers of bony bream in November and December and higher numbers for the species in April. The lack of evidence for spawning from the available species pool is discussed in relation to environmental setting and food availability. The adequacy of occasional flow releases to support healthy fish populations in the Lower Balonne will also be discussed.

33

Modelling the impacts of reservoir expansion on a threatened riverine fish

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Freshwater biodiversity is in crisis. Increasing human population growth continues to stress riverine ecosystems through the compounding impacts of river regulation, acknowledged as a leading cause of biodiversity decline. The global expansion of dams in the 21st century provides water security for consumptive purposes often at the expense of aquatic biota. Many studies have detailed the negative impacts of dams on fish, including the loss of migratory pathways, reduced access to preferred habitat and cold-water pollution and focus on downstream impacts, with fewer studies on the impacts of dams on fish upstream. In this study, we modelled the impact of reservoir expansion on a threatened native fish, two-spined blackfish, *Gadopsis bispinosus*, residing above the Cotter Dam and below Bendora Dam. Two processes were examined in the model, 1. loss of breeding habitat and, 2. increased predation. These threatening processes were assessed using the expected minimum population size as an indicator of risk.

Model outcomes suggest that the two-spined blackfish population is vulnerable to the loss of breeding habitat, particularly if the species is unable to spawn in the lentic dam waters. However, impacts are ameliorated when the 'whole of reach' (between the two dams) is considered. Two-spine blackfish were also found to be vulnerable to low levels of predation by trout residing in the reservoir, particularly if the trout population have a high growth rate. We hypothesised that reservoir expansion (and subsequent inundation) would result in an increase in primary productivity, driving an increase in goldfish (trout food) numbers, resulting in rapid trout population growth that would have detrimental impacts on the two-spined blackfish population. We use a population model to predict the outcomes of dam expansion on a threatened native fish species.

34

Abiotic drivers of Murray cod activity rates

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Understanding how fish respond to changes in their environment provides us with essential information on their needs, facilitating improved management. We examined the abiotic drivers of variability in activity of Murray cod (*Maccullochella peelii*), a large freshwater fish endemic to south-eastern Australia. Accelerometer-derived activity was continuously recorded for six months from

18 individuals occupying a discrete reach of river. Activity was highest during crepuscular and nocturnal periods when water temperatures were warmest (19–30°C; January – March). As water temperatures cooled (9–21°C; April – June), Murray cod were active throughout the full diel cycle and dormant periods were rarely observed. Light level, water temperature and river discharge all had a significant, non-linear effect on activity. Activity peaked during low light levels, at water temperatures of ~20°C, and at moderate discharge rates within the normal operating range for this system. The temporal changes observed in the behaviour of Murray cod likely reflect the complex interactions between physiological requirements and prey resource behaviour and availability in driving activity.

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Time-energy budgets derived from animal-borne instruments clarify the responses of fish to changing temperatures

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Environmental conditions can have substantial impact on a species' success and quantifying and/or forecasting the response of biodiversity to change is of great importance in the Anthropocene. In ectotherms, thermal performance curves of physiological traits are generally used to predict how changes in temperature may impact individuals and by extension populations. However, these generally do not consider other ecological constraints that may be faced by free-ranging animals. Quantification of the thermal sensitivity of time and energy budgets offers an opportunity to account for both ecological and physiological performances. Here we show how modern animal attached accelerometers integrated with laboratory studies can be used to generate time-energy budgets and describe their temperature dependence in free-ranging juvenile sharks. Overall, all time budgets revealed an increase in incidence of time engaged in behaviours related to prey capture, such as prey manipulation and burst swimming behaviour that exceeded the increase of metabolic rate with temperature. Whereas metabolic rate increased exponentially with temperature, our proxies of prey capture indicate that fewer prey were caught at extreme temperatures. Importantly, the optimum temperature for prey capture was below that of locomotor performance, suggesting that purely physiological traits may overestimate critical temperatures for wild individuals.

36

Accelerometers forecast behavioural response to climate change in critically endangered sawfish

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The Fitzroy River in the Kimberley region of Western Australia represents one of the last intact nursery habitats for the critically endangered freshwater sawfish (*Pristis pristis*). However, this region is under increasing threats from both climate change and land use actions, which include proposals for significant water extraction to fuel agricultural development. Both of these factors have the potential to substantially change the physical characteristics of this crucial nursery habitat, including river flow rates and water temperatures. Understanding how sawfish will respond to these changing environmental variables is thus crucial to informing conservation measures for these animals and their unique ecosystem. Here we use a combination of respirometry and accelerometry methods to decipher patterns of behaviour and energy use in free-ranging sawfish. Field energy expenditure, activity levels, and body condition are compared between multiple years within 2011-2017 characterized by significant wet seasons and resulting high water levels, flow rates, and generally lower temperatures, and by poor wet seasons, low flow rates, and higher water temperatures. Results are discussed in the context of forecasting how sawfish may respond to climate change and land development in the Fitzroy region, and informing management and conservation measures for this critically endangered species.

37

Effects of ocean acidification and warming on behavioral and metabolic traits of a large pelagic fish

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Ocean acidification and warming are predicted to increase in the near future, but their effects and complex interactions on large pelagic fishes are not well known. Here, we determined the effects of elevated CO₂ and temperature at projected end-of-century levels on activity levels, boldness, and metabolic traits in larval kingfish (*Seriola lalandi*). Kingfish were reared from the egg stage to 25 days post-hatch in a full factorial design of ambient and elevated CO₂ (~500 μatm and ~1000 μatm) and temperature (21°C and 25°C). Activity levels were higher in fish from the elevated temperature treatment compared with fish reared under ambient temperature. However, elevated CO₂ did not affect activity, and boldness was not affected by either elevated CO₂ or temperature. Both elevated CO₂ and temperature resulted in increased resting oxygen uptake rates compared to fish from ambient conditions, but neither affected maximum oxygen uptake rates. These findings suggest that elevated temperature has a greater impact on behavioral and physiological traits of larval kingfish than elevated CO₂. However, elevated CO₂ exposure did increase resting

oxygen uptake rates and interacted with temperature in complex ways. Our results can inform science and aquaculture about the future outlook of large pelagic fishes.

38

A growth-promoting agricultural pollutant alters ecologically important behaviours in fish

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The capacity of pharmaceutical pollution to alter behaviour in wildlife is of increasing environmental concern. A major pathway of these contaminants into the environment is the treatment of livestock with hormonal growth promotants (HGP), which are highly potent veterinary pharmaceuticals that enter aquatic ecosystems via effluent runoff. Hormonal growth promotants exert biological effects at low doses and have been detected in ecosystems worldwide. However, despite being shown to alter key fitness-related processes (e.g., development, reproduction) in various non-target species, relatively little is known about the potential for HGPs to alter ecologically important behaviours, especially across multiple contexts. Here, we investigated the effects of exposure to a field-realistic level of 17 β -trenbolone—an androgenic HGP metabolite that has repeatedly been detected in freshwater systems—on a suite of ecologically important behaviours in female eastern mosquitofish (*Gambusia holbrooki*). We found that 17 β -trenbolone exposure altered activity and exploratory behaviour in a novel environment, sociability towards a shoal of conspecific females, as well as foraging behaviour when presented with an unfamiliar foraging task. Together, these findings highlight the potential for sub-lethal levels of pharmaceuticals to alter sensitive behavioural processes in wildlife across multiple contexts, with potential ecological and evolutionary implications for exposed populations.

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A psychiatric pollutant compromises antipredator behaviour in fish.

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Wong¹

1. Monash University, Melbourne

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Pharmaceutical pollution is a global environmental problem. Of particular concern are psychotherapeutic drugs with the capacity to adversely impact exposed wildlife at extremely low concentrations. Here, we investigate the impacts of the antidepressant fluoxetine—one of the most commonly prescribed psychotherapeutic drugs and one of the most frequently detected in the environment—on the behaviour of aquatic wildlife. More specifically, we address the impacts of fluoxetine on antipredator behaviours of the Eastern mosquitofish (*Gambusia holbrooki*) using two ecologically realistic dosages. We found that fluoxetine exposure at the lower dosage resulted in increased activity levels irrespective of the presence or absence of a predator. Additionally, fluoxetine-exposed fish, at both concentrations, entered the predator 'strike zone' more rapidly. In a separate experiment, we showed that at just 8 ng/L fluoxetine exposure reduced freezing behaviour, a typical antipredator strategy, following a simulated predator strike. To date, this is the lowest concentration reported to affect the behaviour of wildlife. Together, these findings suggest that exposure to psychiatric pollutants, like fluoxetine, can alter antipredator behaviour in fish at field detected concentration and, in doing so, may impact the fitness of exposed wildlife.

40

Local larval retention and dispersal results in distinct environmental histories in a temperate reef fish

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Marine reef organisms often reside in highly fragmented patchworks of populations interconnected by dispersal of larvae through a hyper-variable ocean matrix. Understanding how and why such fragmented populations fluctuate is essential to predicting extinction risk and responses of populations to environmental change, management strategies, and harvest. Although larvae may routinely be "lost" from parental populations and "captured" by distant populations, we know virtually nothing about true movement potential of the young of most marine species. Using a novel application of moored and drifting light traps, we show that both assemblage-level comparisons and analyses of "environmental fingerprints" contained within the ear bones of larval fish can be used to characterize the effects of ocean matrix features on larval movements and hence connectivity among fragmented marine populations.

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Recruitment and habitat use of juvenile fish in the challenging macrotidal environment of the Kimberley

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4. Western Australian Museum, Perth, WA, Australia
5. Fisheries, Department of Primary Industries and Regional Development, Perth, WA, Australia

Recruitment in the marine environment is a key ecological process which is highly variable in space and time. Fish are known to recruit to different habitat types, sometimes only for a short 'nursery' phase before shifting to adult grounds. In the Kimberley region of north-western Australia, very little is known about fish recruitment and juvenile processes, or how they are affected by a macro-tidal system. More than 600 remote underwater video recordings were made with the aim of answering fundamental questions on spatial and temporal variation in recruitment and juvenile habitat use in the Kimberley. For most species, recruitment primarily occurred during the wet season (October-April) across a diverse range of Kimberley habitats. Coral reef, macroalgae, seagrass and mangrove habitats all supported different species assemblages with some species recruiting into a single habitat type. Surprisingly, we found that fish diversity was below expectations considering the Kimberley's close proximity to the equator and global centre of fish diversity. These results prompt questions about the influence of the Kimberley's unique challenging environment and its effects on the supply and survival of juvenile fishes and argue strongly for targeted and representative protection of all Kimberley habitat types as fish nursery grounds.

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Evaluating the contributions of black bream (*Acanthopagrus butcheri*) spawning tributaries to year class strength in the Gippsland Lakes using otolith trace element fingerprinting

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Black bream (*Acanthopagrus butcheri*) is a commercially and recreationally important species that is prevalent in southern Australia, with Gippsland Lakes being the most important commercial fishery in Victoria. Despite being long-lived, there are typically only a few dominant age classes sustaining the fishery, due to large interannual variability in recruitment. Although black bream spawn daily over a 2-5 month period, the catch numbers in the Gippsland Lakes have been in decline since the mid-1980s. To investigate the sources of variation in recruitment of black bream as well as to determine the spatial distributions of natal cohorts, we sampled juveniles from all accessible seagrass beds throughout Lake King over the autumn months of 2015 and 2016. We extracted sagittal otoliths from caught juveniles and analysed their cores using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). We used the chemical signatures from these analyses to reconstruct natal groups and to provide insight into the relative contribution of tributaries to year class strength and recruitment. Our results will allow for the management of this iconic and essential fishery both in terms of identifying key spawning locations and the drivers of year class strength.

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Within-season changes in otolith microstructure and chemistry expose the complex early life history of a temperate marine finfish

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Understanding the early life history of fish is essential for investigating population dynamics, spatial connectivity and stock structure, which contribute to developing highly-resolved fishery management strategies. This study considered King George whiting (*Sillaginodes punctatus*), the most significant inshore fishery species of southern Australia. It explored the early life history of recruits to a significant nursery area in Gulf St. Vincent, South Australia. Post-larvae were sampled fortnightly throughout the July to November settlement period and the early life history retrospectively reconstructed using otolith microstructure and elemental chemistry. Back-calculated spawn dates covered a four month period from March through June, whilst spawning during a short, three week, period in May contributed most to recruitment. Trace element chemistry analysis considered the natal origin of the same fish and identified two different multi-elemental signatures that related to fish spawned up until April, and those spawned thereafter. This within-season temporal change in otolith chemistry reflected higher ⁸⁶Sr and lower ⁷Li later in the spawning season, and suggested two possible scenarios: either a change in environmental conditions that considerably influenced otolith chemistry; or there were two different natal origins. These findings emphasize the importance of considering within-season variability in life history studies.

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A new method for non-destructive high resolution oxygen isotope analysis of otoliths

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Otolith geochemistry is a mainstay of fisheries research, providing individual and population-scale life history information. Oxygen isotopes incorporated into the otoliths from the surrounding water act as proxies for water temperature and can be used alone or in conjunction with trace element data to infer ontogenetic movement. Oxygen isotope data are typically obtained through micromilling otoliths which limits the resolution of the resulting data. Secondary Ion Mass Spectrometry (SIMS) uses ion beams of as little as 5um to obtain a high temporal resolution and allows oxygen isotopes to be studied in much finer detail than previously possible. The pros and cons of SIMS will be discussed and preliminary results from SIMS analysis of two co-occurring species of fishes from the Pilbara will be presented.

45

Is critical speed the best measure of swimming capabilities for fish larvae?

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Larval marine perciform fishes have significant swimming abilities for much of their pelagic larval dispersal stage (PLD). This gives them the ability to directly influence their dispersal. However, there are several ways of measuring swimming ability, and in the context of dispersal, it is not clear which is the most appropriate. It is important to use the right swimming measure not only for modelling dispersal, but also for use in predicting both demographic and genetic connectivity. Recently, Nanninga & Manica (2018, MEPS, 589:1-12) concluded that for marine, demersal fishes "larval swimming capacities could serve as a powerful indicator of a species' long-distance dispersal potential", and were a better predictor than PLD. As their metric of swimming capacities, Nanninga & Manica used mean critical speed (U-crit), which is measured in a laboratory raceway by incrementally increasing flow until the larva cannot maintain position. I will examine the suitability of U-crit versus other swimming metrics, in particular *in situ* speed. The among-individual variability of swimming performance will be stressed, as will the ontogeny of swimming ability.

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Fisheries integration across the Pacific: Australia and Chile.

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1. CSIRO, Hobart, TASMANIA, Australia

Since the late 1980s, the production of Chilean Austral zone fisheries has declined by more than 70%. Recently, a joint research project between CSIRO and Chile has been developed with the aim of establishing a 'Science-based Management Strategy for Rebuilding Chilean Fisheries', including long-term sustainability and capacity-building for the demersal Austral zone fishery. To promote the collaboration, a recent workshop in Chile led by CSIRO scientists provided training and background on Management Strategy Evaluation (MSE) to Chilean scientists. MSE is a simulation-based method used to test the robustness of alternative fishery management strategies. Two case studies using MSE based on Patagonian grenadier and Southern hake were used to examine the consequences of different model structures on stock assessment outcomes. These model structures underpin the harvest strategy used to set the annual total allowable catch. This talk will provide background to Chilean fisheries, example applications of MSE for Chilean stocks and an overview of the Australia-Chile collaboration.

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Socially responsible stingray fishing rules - working with all stakeholders to achieve a balanced solution

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Stingrays and banjo sharks are valued by the Victorian community for the contribution that they make to their ecosystems, the enjoyment that they bring to snorkelers, divers, pier visitors and tourists, and the food and enjoyment they bring to some recreational fishers and seafood consumers. There is no indication of sustainability issues for these species in Victorian waters.

In 2017, a high profile community campaign emerged in Victoria highlighting disrespectful fishing behaviour for rays and banjo sharks by a small proportion of recreational fishers.

Our presentation will focus on how the VFA has responded to changing community attitudes to ensure that our recreational fishing rules for stingrays remain socially acceptable, alongside our continued focus on responsible recreational fishing. The outcome of our work has been new recreational fishing rules that are well accepted by all stakeholders, and better, more balanced management of stingrays across Victorian waters.

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Enhancing the human nutrition and livelihood benefits from a small-scale, small-pelagic fishery

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2. *Research School of Biology, The Australian National University, Canberra, ACT, Australia*

Fish are essential as income and food in many developing countries. In the international policy arena, there is increasing emphasis on promoting 'nutrition-sensitive' fisheries – which focus on enhancing social, food security and human nutrition benefits. But what does this actually mean for practical fisheries management? And how do the ecological complexities that underpin fisheries resources constrain or enable this type of approach? In Timor-Leste, a country with widespread poverty and undernutrition, small-pelagic fisheries are small-scale, under-developed and un(der-) regulated, and hence there is potential to enhance these fisheries' contributions to people's diets and livelihoods. Using Timor-Leste's sardine fisheries as a case-study, this paper explores the social and biophysical challenges and opportunities for developing a sustainable fishery with a 'nutrition-sensitive' approach. These fisheries are seasonal and comprised of mixed species; catches fluctuate from year-to-year and there is limited data on stock size or connectivity. Through this study, it is concluded that a nutrition-sensitive approach requires a whole-of-(food)-system perspective. While increasing fish supply through higher catches may lower prices and increase economic access to fish, other food system components should also be addressed, such as reducing post-harvest waste, promoting processing opportunities and food safety, and public awareness to encourage fish consumption.

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Keeping pace with market shocks

Blake Taylor¹

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Upward trending price shocks in any portion or cut of a seafood product has the potential to rapidly undermine management as a 'gold rush' mentality develops. Whilst the priority of fisheries management is to control harvest at sustainable levels, that task becomes complex under such circumstances, particularly when resources are over-exploited. Over the last decade Black Jewfish have experienced increasing levels of exploitation around Darwin where there are high levels of fishing pressure from all fishing sectors. In 2015, a range of measures were introduced to protect Black Jewfish stocks from overfishing, including commercial quotas, vessel limits and spatial closures. Since then, research into Black Jewfish stock structure has indicated that populations are more discrete than previously understood and exist at much finer spatial scales along the coastline. Fishing pressure on these discrete Black Jewfish populations is still increasing and is now driven by the demand for their swim bladders, with market values ranging between \$550 and \$850 per kilogram. This market driver now threatens to undermine the management in place to recover Black Jewfish stocks around Darwin and it is vital that new arrangements are developed to ensure the long-term sustainability of Black Jewfish as a fishable resource.

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Integrating customary rights into fisheries management

Shane Holland¹

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The 1992 High Court Mabo decision recognised native title rights in Australia and led to the enactment of the *Native Title Act 1993* (Cth). Section 211 of the Act provides for the exercise or enjoyment of native title rights in relation to land or waters for carrying out activities for the purpose of personal, domestic or non-commercial communal needs and in exercise of their native title rights and interest.

Aquatic resources in South Australia are managed in accordance with the *Fisheries Management Act 2007*. The Act recognises Aboriginal traditional fishing as a unique and distinct fishing sector, and allows for the implementation of Aboriginal traditional management plans. This approach effectively links native title legislation with fisheries legislation to ensure that Aboriginal customary fishing activities can be protected and managed consistent with the objectives of both sets of legislation.

The Traditional Fisheries Manager within PIRSA Fisheries and Aquaculture provides a dedicated position for ongoing engagement with Aboriginal communities regarding their interests and rights, and for the development of tailored fishery management arrangements. The appointment assists in strengthening a positive relationship between Government and the Aboriginal community, and developing new economic and employment opportunities in fisheries related industries.

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Understanding the feasibility of using artificial habitats to protect galaxiid populations in yingina / Great Lake

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2. *Entura, Cambridge, Tasmania, Australia*

yingina/Great Lake is located in the central plateau area of Tasmania, a region renowned for its high degree of aquatic faunal endemism. Populations of the threatened Shannon paragalaxias (*Paragalaxias dissimilis*) and Great Lake paragalaxias (*Paragalaxias electroides*) occur throughout the lake, and are closely associated with the lake's benthic habitats.

yingina/Great Lake is a mainstay of Tasmania's hydropower system, particularly during dry periods. Record low rainfall during spring 2015, and a significant fault in the Basslink undersea interconnector, led to increased reliance on the lake for power generation, with water levels falling to the lowest on recorded since the 1967 drought. Water management operating constraints were successfully implemented for the lake to reduce the potential threat to *Paragalaxias* populations, namely dewatering of rocky, littoral, non-embedded spawning habitat and dewatering of eggs.

It was recognised that the use of artificial spawning habitat could also be a potential mitigation measure to reduce the impact of extreme event related habitat loss, however the feasibility and effectiveness of using artificial habitats was not known. A pilot study was implemented to test the suitability of a range of naturally occurring and manufactured spawning substrates, and the preliminary results of this research are discussed.

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Continuing the recovery of barred galaxias - learning by doing

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Barred Galaxias (*Galaxias fuscus*) is a small, non-migratory freshwater fish endemic to a small range in the upper reaches of the Goulburn River system in central northern Victoria and is listed as Endangered under the Commonwealth EPBC Act 1999. The main threat to the remnant and isolated populations are predatory fish; introduced trout. All remaining populations of galaxiids are located upstream of barriers which prevent colonisation by predators, however, not all barriers are 100% effective. Within the last few years three successful translocations have occurred and a barrier has been upgraded. We have used previous predator detection, environmental and physical data, and assessment of all the known barriers, to develop a risk model to prioritise sites for continued monitoring. We demonstrate adaptive management in long-term recovery projects, and the importance of previous investment to this process to secure this species into the future.

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Immigration of silver perch into tributary streams of the Murray River and the influence of streamflow

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The silver perch (*Bidyanus bidyanus*) is a nationally threatened native fish species found in lowland rivers of the Murray Darling Basin. Populations have declined in abundance and range, due to factors such as altered flow regimes and fragmentation. In this project, we use acoustic telemetry to investigate immigration of silver perch into tributary streams of the Murray River, and the role of streamflow, including multi-river coordinated environmental flows, in facilitating movement. This information is needed to improve our understanding of movement ecology, particularly the effects of flows on movement, and to ensure environmental water entitlements are used to achieve the best environmental outcome with the water that is available. Preliminary results suggest that immigration may be an important driver of population dynamics, with this process linked to patterns of hydrology. Based on the findings, appropriately designed and coordinated environmental flows, across river networks and large spatial-scales could be represent an important targeted management action to promote tributary fish population recovery for the species.

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An application of flagship species and broad scale aquatic biodiversity indicators for potential water resource developments in northern Australia

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Sustainable water resource planning in northern Australia requires informed aquatic ecological input in order to determine the potential environmental impact. However, an absence of complete ecological knowledge inevitably confounds the process. Incomplete ecological knowledge and understanding is pronounced in parts of northern Australia as a function of the remoteness and a reduced scientific legacy relative to more developed parts of the continent. This presentation describes efforts to conceptualise and model fish responses to potential water resource development and particularly changes in flow regime and connectivity as a consequence of potential dams and water harvesting. Three phases of analyses were implemented: formulation of conceptual model narratives, hydrometric analysis and a preference curve approach. This approach proved informative for

exploring a range of scenarios incorporating both development and climate change scenario. The application is used to explore broader themes of incomplete knowledge in the context of fish, considering flagship species and biodiversity indicator species and functional groups of species in the context of water resource planning. We demonstrate this using catchments distributed across northern Australia.

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Screening the Cohuna Channel diversion to keep native fish in Gunbower Creek

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2. Victorian Environmental Water Holder, Melbourne, Victoria

Fish entrained in irrigation channels are exposed to poor quality habitat, low-to-no over winter flows, increased predation, injury or death from irrigation pumps, and usually have no passage to return to the natural system.

In the USA and Europe, self-cleaning screens limit fish movement into waterways, hydropower stations and pump houses. In many of these instances screens are required under legislation, resulting in a well-established and innovative industry.

Larval drift surveys undertaken by North Central Catchment Management Authority (NCCMA) in Gunbower Creek over November-December 2017 revealed that approximately 5,500 fish larvae from four species, including more than 160 Murray cod larvae, are being entrained per day in the Cohuna Channel during the peak larval drift period.

To prevent these losses, NCCMA in partnership with the Victorian Environmental Water Holder and AWMA Water Control Solutions, are installing Australia's first self-cleaning irrigation channel screen to prevent fish entrainment from Gunbower Creek to the Cohuna Channel. The screen has been designed to suit the needs and spawning strategies of Murray-Darling Basin fish species. The design builds on the extensive knowledge of AWMA and their industry partners in the USA, factoring in local hydrology to ensure the delivery of irrigation water is not impeded.

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Fish Passage in streams of the Gulf of Carpentaria, unique life histories driven by highly variable flow regimes

Tim Marsden

Throughout streams of the Gulf of Carpentaria (GOC) the passage of migratory fish is critical to the ongoing maintenance of fish populations. The highly irregular nature of flows within these systems creates a diverse range of permanent and intermittent fish habitats. Fish populations need free movement within and between these habitats, with adults needing to reach suitable spawning habitats, often in the sea, and juveniles needing to disperse into nursery habitats to grow or to recolonise previously dry habitats. The construction of several fishways on tidal barriers within streams of the GOC has provided an opportunity to examine the migratory behavior of many species that have previously been poorly studied. Results from fishway sampling has demonstrated that a wide range of species previously thought to be non-migratory are undertaking migrations within these systems, often as both juveniles and adults. These results link the diverse flow regimes of these intermittent streams to the migration requirements of the local fish communities and highlights the highly important role fish passage remediation at barriers plays to maintaining fish communities in these systems.

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Environmental change in early ontogeny influences cognitive ability in intertidal gobies

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Behavioural plasticity is an advantageous trait for animals living in dynamic environments, and can be induced through learning. While some behavioural traits are innate, others are framed by experience and learning in an individual's lifetime. Many studies have investigated cognitive abilities in species from contrasting environments, but the relative contribution of natural selection versus behavioural plasticity in cognitive variability remains equivocal. Further, laboratory husbandry is often standardised, failing to encourage natural behaviour in these studies. Here, we captured juvenile gobies (*Bathygobius cocosensis*) from intertidal rockpools, and raised them in captivity under varied environmental enrichment treatments that mimic variation observed in their natural habitats. When tested in a simple spatial learning task, individuals from complex treatments (rock or oyster substrate) reached learning criteria faster than those from homogenous treatments (sand or sea grass substrate). Interestingly, complex treatment gobies demonstrated longer latencies to start the task than gobies in homogeneous treatments. Despite originating from a highly dynamic environment, gobies reared in homogeneous treatments showed a deficit in spatial learning ability. Our results indicate that cognitive ability is strongly shaped by individual experience during early ontogeny, and exposure to reduced environmental complexity leads to reduced cognitive abilities in intertidal gobies.

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Long-term changes in sociality of butterflyfishes linked to population declines and coral loss

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Butterflyfishes have evolved critical relationships with scleractinian corals and are extremely vulnerable to widespread reef degradation and coral loss. Temporal changes in composition and abundance of butterflyfishes has been documented at Lizard Island, northern Great Barrier Reef, which has been subject to several recent and major disturbances. The purpose of this study was to examine temporal changes in the social structure (sociality) of the *Chaetodon* butterflyfish assemblage at Lizard Island to explore implications for reproductive viability of remaining individuals after disturbance. We predicted that declines in the abundance of butterflyfishes caused by depletion of prey resources, would disrupt social systems leading to declines in proportion of individuals found in pairs. Sampling was undertaken to quantify the abundance and sociality of butterflyfishes at Lizard Island, testing for changes in the proportion of individuals that occurred in pairs in 2002, 2009 and 2017. While there is an unequivocal decline in the abundance and diversity of *Chaetodon* butterflyfishes after coral loss, the effect upon sociality was variable across species. Overall coral loss led to a significant negative effect on sociality, but this varied greatly amongst species, from a significant negative effect (*C. baronessa*) to no significant effect (*C. citrinellus* and *C. vagabundus*).

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Halos of fear: the impact of predation threat on feeding behaviour of mesopredatory fishes around patch reefs

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Fishing is rapidly removing sharks and other large predators from coral reefs, but at present we lack a complete understanding of the ecological role of these predators in such environments. It is known that sharks are likely to exert strong ecological effects on their prey either directly through consumption, or indirectly by inducing antipredator-or "risk effects"- behaviours, however direct experimental evidence of such behaviours are rare. Using life-size models of threatening (reef sharks) and non-threatening (turtles, small fishes) taxa, we examined the impact of perceived predation threat on the feeding behaviour and spatial use by mesopredatory reef fishes in a coral reef environment. Preliminary results show that the presence of a model reef shark increased the time taken for mesopredatory species to consume prey items and suppressed feeding at larger distances from the reef edge. A model coral trout did not increase the time taken for mesopredatory reef fishes to consume all available prey items compared to a negative control (no model). The use of life-size models has provided some of the first evidence for the existence of risk effects caused by large, high-order predators on mesopredatory fishes in coral reef environments.

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Seeing Red: The role of long wavelength sensitive cones in the visual ecology of bluestriped goatfish

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The bluestriped goatfish (*Upeneichthys lineatus*) occurs along the south-eastern coast of NSW, Australia. Its body colouration and pattern is highly dynamic, changing from plain white to a red pattern colour when foraging. It is possible that the red patterning is a foraging signal to conspecifics. To establish whether the red pattern colour is a means of communication amongst conspecifics, it is first essential to understand what colours these goatfish can see. Using both physiological and behavioural experiments, we examined whether *U. lineatus* possesses visual pigments with sensitivity to long (red) wavelengths of light. Behavioural (operant conditioning) colour discrimination experiments suggest that wild-caught individuals can distinguish a red reward stimulus from grey distractor stimuli of variable brightness. Initial data from microspectrophotometry show that *U. lineatus* have several spectrally distinct cone photoreceptor types, some with sensitivity to longer wavelengths. Given other species of NSW goatfish lose the red sensitive visual pigment on settlement due to changes in the light environment, it is feasible that the capacity for *U. lineatus* to discriminate the colour red may provide an advantage in recognising possible signals from conspecifics. This research is key in furthering our understanding of communication systems in the marine environment.

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Fatal Attraction: Factors influencing mate preference in the Running River Rainbowfish

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Hybridisation and subsequent introgression threaten many species world-wide through the loss of genetic and species diversity. The Running River rainbowfish is one such species. As multiple species of *Melanotaenia* are threatened by introgressive hybridisation with *Melanotaenia splendida* we decided to investigate the factors influencing hybridisation with *M. splendida*. This was achieved through the use of mate selection and cross-breeding experiments. Here we present the bulk of our findings.

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Quantification of colour patterns reveals rapid differentiation and conflicting geographic range effects on reef fish colouration

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Colouration is important in mate recognition and selection. The 'species recognition hypothesis' predicts that sister species with overlapping ranges will have greater colour pattern divergence. We tested this hypothesis with brightly coloured coral reef butterflyfishes (genus: *Chaetodon*). Using a novel digital imaging methodology, we quantify both colouration and pattern using 250,000 sample points on each fish image. Surprisingly, evolutionary age did not affect colour pattern dissimilarity, with large colouration differences between sister pairs already established within 300,000 years. However, the effect of range overlap and range symmetry were significant. Sister species colour patterns become more dissimilar with increasing overlap, but only when ranges are similar sized. When ranges are disproportionate, sister species colour patterns become more similar with increasing overlap. Species with small ranges appear to maintain non-colour based species boundaries.

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Seasonal dynamics of tidal pool fish community in the Seongsan of Jeju Island, Korea

Hyuck Joon Kwun, Chang Ho Yi

This study investigates the composition and abundance of tidal pool fish in Seongsan of the Jeju Island, Korea. The fishes were sampled every month from January to December 2017. A total of 463 specimens were sampled, which belonged to 51 species in 23 families including two unidentified species. Labridae (6 species), Gobiidae (6 species), and Blenniidae (5 species) species were predominant taxon. *Dictyosoma rubrimaculatum* and *Enneapterygius theostomus* were most present during 9 months in the year. In terms of period, abundance was the highest in August and September as 20 species, and lowest in the February as 4 species. On the other hand, diversity index was the highest in June ($H'=1.155$), and lowest in February ($H'=0.538$). Total biomass was the highest in May (179.11g), and lowest in February (8.51g). In cluster analysis, two differentiated seasonal group was confirmed (from December to March and April to November), but August and October show unusual aspect in comparison to other seasonal compositions. Compared to the previous study, fifty-one species in this study is lower than previous reported, but seventeen species represent new records for the Seongsan. Therefore, it seems that tidal pool on Seongsan is used for habitats of many more fishes.

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Distribution, ecology and potential establishment of the non-native ocellate river stingray *Potamotrygon motoro* (Potamotrygonidae)

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The South American ocellate river stingray, *Potamotrygon motoro*, was reported from an artificial reservoir in Singapore in 2009, but there have been no further studies since. We aimed to investigate the distribution and ecology of this species, and surveyed 12 reservoirs with multiple methods, capturing 34 adults (1♂:1.32♀) that included several pregnant females, and 24 juveniles from three reservoirs (two new reservoirs plus the original locality). Gut content analyses reflected a varied diet that mainly comprised macroinvertebrates (e.g., gastropods). This was supported by stable isotope analyses, which found the benthopelagic *P. motoro* to be in a distinct trophic guild from other pelagic carnivores in the reservoir. As Singapore remains the only place outside South America with established populations of non-native *P. motoro*, and in view of its popularity in the international aquarium trade, we conducted Species Distribution Modelling (SDM) to estimate its potential to establish in other parts of the world. Our SDMs revealed that *P. motoro* could become established in a range of countries including China, Japan, USA, Taiwan, and Malaysia. Issues surrounding its introduction pathway in Singapore and potential spread into natural forest streams that are important refugia for native species will also be discussed.

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Dietary comparison of the tropical herbivore *Siganus fuscescens* and a range of temperate seagrass-associated omnivorous fishes

Casper S Avenant

Rising sea temperatures are facilitating range shifts of tropical biota towards higher latitudes. The rabbitfish *Siganus fuscescens*, a tropical herbivore, has become a regular sighting along rocky reefs and in seagrass meadows of temperate southwest Western Australia and southern Victoria. *Posidonia*-dominated habitat was trawled in two nearshore locations in Perth, WA, to determine whether the diets of *S. fuscescens* were similar to a range of temperate seagrass-associated omnivorous fish species through gut content analysis, and whether it is likely to enhance seagrass grazing rates in temperate meadows. While seagrass was consumed by *S. fuscescens* in large quantities at one site, corticated terete rhodophytes (*Hypnea* & *Chondria*) and leathery heterokontophytes (*Ecklonia* & *Sargassum*) were consumed in greater quantities at the other site. In comparison, the temperate omnivores *Haletta semifasciata*, *Heteroscarus acroptilus* and *Scobinichthys granulatus* consumed seagrass in high quantities, but showed distinct interspecies differences in their diets.

Exploring spatial heterogeneity of algal removal by herbivorous fishes on coral reefs

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Our current understanding of coral reef resilience relies on the assumption that the herbivorous fish community keeps algae in check across the entire reef. Based on this understanding, assessments of ecological resilience quantify biomass of herbivorous fishes and consider a fish's presence in an area as a proxy for the spatial extent of algal removal. However, feeding is unlikely to occur homogeneously over a fish's entire home range. This broad-scale approach appears to be a key weakness in our current evaluations of reef resilience. Especially in recent times of dynamic perturbations on coral reefs, it is critical to understand how feeding by herbivorous fishes is driven by and can respond to small-scale shifts in benthic conditions. To explore space use and density of feeding by herbivorous reef fishes as a new facet of reef resilience, this research utilizes a novel approach using underwater video assays recording the feeding activity of any fishes over replicate 36 m² areas. Findings to date suggest that the cumulative feeding impact of multiple functional groups appears to be spatially focussed, showing high levels of spatial overlap and concentration - with large areas of benthic space remaining functionally untouched.

The ecology of important subsistence fishery species under varying environmental conditions

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Reef fish are an important commodity for both human populations and coral reef ecosystem processes. In developing island nations, fish from multiple trophic levels are exploited, potentially compromising ecosystem function. For example, in the Philippines, large-bodied planktivorous and herbivorous *Naso* and *Siganus* are valuable subsistence fishery species. This study uses stable isotope analysis of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ from fish muscle tissue and primary source samples to investigate the plasticity in diet and trophic ecology of *N. unicornis*, *N. lituratus*, *N. minor* and *S. virgatus*, caught near inshore (mainland) and offshore islands. We hypothesize differences in primary production and terrestrial nutrient input between island types are contributing to variation in diet and trophic level. Thus, we expect individuals inhabiting platform reefs on small offshore islands will have different signatures than the same species on mainland island fringing reefs. Further, relative nutrient availability among island types is inferred by comparing carbon and nitrogen ratios from algal sources collected from multiple sites on these island types. With expanding human populations, coastal development and a changing climate modifying coral reef fish assemblages globally, understanding whether the diet of important reef fish is influenced by environmental conditions is question of significance.

Damage-resilient *Sargassum* holdfasts are not targeted by herbivorous fishes

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As stressors impacting coral reefs increase, understanding the role of herbivorous fish in controlling the proliferation of macroalgae on coral reefs is vital. However, previous studies investigating fish herbivory of macroalgae (particularly *Sargassum* spp.) have only investigated removal of the 'leafy' biomass and have not investigated whether fish remove *Sargassum*'s holdfast, despite *Sargassum*'s ability to rapidly regrow from holdfasts. To investigate the impact of herbivory on the different components of *Sargassum* (in particular the holdfast), we placed *Sargassum* attached to coral rubble (rocks) on the reef crest at Lizard Island, Great Barrier Reef, for 3.5 weeks, identifying the fish species responsible for *Sargassum* removal and quantifying rates of removal using video recordings. All blades were removed from deployed *Sargassum* within two days, predominantly by *Naso unicornis*. However, only one out of 54 holdfasts was removed during the experiment and none of the remaining holdfasts decreased in size relative to caged controls, despite recording over 800 bites on the rocks by 29 fish species. With no fish species obviously targeting *Sargassum* holdfasts, these findings indicate that holdfast removal is unlikely to be rapid on coral reefs, which may contribute to the persistence of *Sargassum* biomass, even in the presence of herbivores.

Applying evolutionary principles in management and conservation for improved outcomes

Stephanie Carlson¹

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There is growing appreciation that management and conservation outcomes could be improved by incorporating evolutionary principles. Here I will provide several examples to illustrate the gains made by incorporating evolutionary principles into management decisions, including examples focusing on the evolutionary and ecological impacts of harvest and aquaculture, and how to minimize those impacts. This body of work highlights the importance of considering biodiversity below the species level in management and conservation efforts. In particular, a focus on population-level variation and variation among individuals within populations (the raw material of evolution) is warranted and necessary. In fact, shifts in intraspecific diversity might serve as an early indicator of undesirable population change. While challenging, conserving or restoring intraspecific diversity within fish populations is a proactive strategy for managing for resilient populations in an era of rapid change.

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Plasticity of marine fish to ocean warming

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Knowledge of the capacity for species to acclimate and adapt to rapid climate change is critical for understanding likely species responses, as well as for effective management and conservation of ecosystems in the future. Much of the research to date uses the present-day performance and sensitivity of populations or species to infer the capacity for persistence in predicted future environments. This research generally suggests negative impacts to most organisms and very little capacity for species to cope with expected future change. However, for marine species projected environmental change will occur over years and generations allowing for plastic and adaptive processes to take place. Recent research is showing that some species may be able to improve and maintain performance when altered conditions are experienced early in life or when previous generations have experienced conditions. I present a series of studies on the ability and limitations of tropical reef fish to acclimate to projected ocean warming within and across generations.

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Informing inter-jurisdictional snapper management in eastern Australia

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Current management arrangements for snapper fishing on Australia's east coast are different between States (New South Wales, Queensland, Victoria) and the Australian Government. They have been informed by different kinds of data and analyses, at least in New South Wales and Queensland which together take the vast majority of the harvest. These differences have led to different conclusions of stock status. Recent research involved the collaboration of stock assessment scientists, biologists, fisheries managers and industry stakeholders from New South Wales, Queensland and Victoria to provide the first joint assessment of the east coast snapper stock informing inter-jurisdictional snapper management in eastern Australia. The latest genetic microsatellite techniques were used to explore the stock structure of snapper along the east coast showing there is a two-stock genetic model for snapper along Australia's east coast, a northern and a southern stock. These results were used to inform a snapper simulation model to inform cross-jurisdictional east coast snapper management on the northern stock. Challenges in the work included harmonising data from different jurisdictions and fitting the model to multiple data sets with different trends. Alternative management strategies on changes to minimum legal size or fixing total allowable harvest were explored.

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Risk-based selection of indicator species for the assessment of multi-species fishery resources in Western Australia

Gary Jackson¹, Stephen Newman¹

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Assessing the status of multi-species fishery resources is challenging especially in highly diverse systems, where catches are small, and comprise many species. While ecosystem-based management in such cases requires assessment of the impact of harvesting on many species, this is impractical. Instead, selected 'indicator' species can be used to assess the sustainability risk of all 'like' species susceptible to harvest within a fishery resource. These indicators are objectively determined using information on their (1) inherent vulnerability; (2) risk to sustainability; and (3) management importance. These attributes are used to develop an overall score for each species which is then used to identify the key 'indicator' species. The current risk status of the indicator species determines the risk-level for the biological sustainability of the entire fishery resource and thus the level of priority for management, monitoring, assessment and compliance. The indicator species approach has been used and refined for fisheries management in Western Australia (WA) over two decades with the process now reasonably well understood and accepted by stakeholders. Case studies involving demersal scalefish resources in North and West Coast Bioregions of WA will be presented to illustrate how this approach works.

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Are simple and cheap stock assessments all that is required?

Malcolm Haddon¹

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Fisheries management attempts to maintain fished stocks above stock depletion levels that increase risks of over-exploitation and potential on-going damage to recruitment. This is rational for maintaining profitable fisheries and retaining ecosystem services provided by such stocks. However, once determined to be sustainably fished how often should formal stock assessments be conducted, and how expensive do they need to be? An array of relatively simple assessment methods are available capable of providing determinations of stock status, providing management advice (catches or effort), and are simpler to explain to stakeholders. Should one continue to use sophisticated stock assessments that can synthesize the implications of a wide array of different data and provide robust solutions to fisheries management problems? Or should one save financial and other resources by not collecting such an array of expensive data time-series (for example ageing data is very expensive) and restricting oneself to relatively simple stock assessment methods? Given the shrinking resources being made available for stock assessments right across Australia this is not a trivial question. This presentation summarizes the case on both sides and puts forward an answer designed to increase the general understanding of this issue and stimulate more informed discussion of this problem.

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Age and length data for integrated assessments – how much is enough?

Paul Burch, Jemery Day, Geoff Tuck, Robin Thomson, Malcolm Haddon, Andre Punt

Modern age-structured stock assessments integrate multiple sources of information within a single assessment framework to provide estimates of stock status. These models usually incorporate catches, and composition data (ages and/or lengths), along with one or more indices of abundance from surveys, catch per unit effort or tagging data.

Composition data provide information on recruitment and cohort strength and are crucial for the application of age-structured assessments. Collection of length data and the ageing of fish from otoliths is expensive so it is important to optimise this process. The number of samples required for robust assessments has previously been estimated using statistical sample size calculations. However, the impact of these decisions on the assessment of species with different life-history characteristics is not well understood.

We investigate methods to simulate correlated age and length samples that approximate those observed in real fisheries. We then use an existing simulation modelling framework that incorporates an age-structured assessment model to investigate the effect of different age and length sample sizes on the ability of age-structured assessments to estimate quantities of management interest for populations with different life-history characteristics.

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Novel methods to assess long-term trends in size and age at maturity in fish: a story of harvest and warming

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2. IMAS, University of Tasmania, Hobart, Tasmania, Australia

Age and size at maturation play key roles in determining the fitness of individuals and underpin population demography. Evidence is growing that fishing and climate change can cause rapid change in life histories by increasing overall mortality and imposing size selectivity on populations. Declines in size and age at maturity can in turn impact on stock productivity as well as result in the loss of valuable phenotypic variation that could buffer populations against further environmental perturbations. Yet, despite the importance of understanding change in maturity schedules, such studies have largely been restricted to northern-hemisphere, high-value stocks where large observational datasets are recorded. Change in age and size at maturity is currently unassessed in Australian fished stocks. We will demonstrate a recently developed ontogenetic growth-modelling technique that can allow us to model age and size at maturity from length-at-age datasets commonly collected by fisheries agencies. Additionally, we will present time-series estimates of maturity in a number of key fish species. This approach could facilitate the recreation of life history schedules over many decades, help understand drivers of potential maturity changes, and improve sustainable fisheries management in rapidly changing future environments.

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Climate-driven species redistribution in marine systems

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Climate change is driving a pervasive global redistribution of the planet's species, with manifest implications from genes to ecosystems across multiple temporal and spatial scales. Species redistribution defies current approaches to natural resource management that focus on restoring systems to a baseline and are often based on boundaries drawn in the past. Changes in distribution of marine resources creates difficulties, particularly when species cross jurisdictional boundaries and where historical catch rates and assessment processes may no longer be appropriate. Moreover, we are still a long way from understanding the suite of mechanisms and processes underlying the high variation in rate and magnitude of shifts. Building on that uncertainty, we have even less understanding of how species redistribution will drive changes in ecological communities and further complicate

aspirations of ecosystem-based management. Climate-driven species redistribution therefore presents intriguing ecological challenges to unravel, as well as fundamental philosophical questions and urgent issues related to ecology, fisheries, food security, Indigenous and local livelihoods, and many other aspects of human well-being. This presentation will highlight some of the progress with adaptation planning and adaptation actions at international, national and local scales. Understanding range shifts from ecological, physiological, genetic and biogeographical perspectives is essential for informing and designing natural resource management strategies for a changing future. However, for species redistribution research to support development of relevant adaptive strategies and policy decisions adequately, studies need to take an interdisciplinary approach and must recognise and value stakeholders.

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Climate change, fish and fisheries revisited: 2010-2018.

John Koehn¹

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In 2010, ASFB hosted a climate change symposium associated with the last conference held in Melbourne. That symposium resulted in a special edition of *Marine and Freshwater Research* titled *Climate change and Australian aquatic environments, fish and fisheries* (<http://www.publish.csiro.au/MF/issue/5635>) that included 12 papers on climate change issues. Here we are in 2018; climate change is still happening, and the keen interest from ASFB and its constituents remains, so we are revisiting this important topic. In this paper I will review 2010, assess our predictions from that time and update our knowledge. This will provide an introduction for the many other valuable papers to be presented on this theme.

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Climate-proofing fisheries management

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2. *AFMA, Canberra, ACT, Australia*

Australian marine systems are undergoing rapid environmental change, with some of the largest climate-driven changes in the Southern Hemisphere. While rapid change is predicted to continue, the magnitude will differ around Australia, as will flow-on effects on local communities and fishing businesses. We will describe recent multi-decadal ecosystem model projections for major fish stocks around Australia. For some fisheries, responses by fished species included both increases and decreases, indicating the potential for switching focal species. In the tropics, large fish stock changes can occur despite small climate changes due to non-linear influences on primary productivity supporting the foodweb. Fishing sectors and managers will need to be flexible if they are to cope with these changes and avoid the worst consequences. Management that is coordinated across State and Commonwealth fisheries and that links with other users of marine waters offers advantages. Healthy fisheries will also require information services that are updated regularly with the latest understanding of what Australia's climate, fish, ecosystems and fisheries are doing. Such information should highlight those species that may be at risk, those that might benefit, and what actions are needed to mitigate undesirable outcomes and make the most of any new opportunities.

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Squeezed out! The impacts of climate change and invasive fish on a threatened galaxiid - north east Tasmania, observations from long term monitoring.

Rob Freeman¹

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Localised climate models, predict the North East area of Tasmania will experience extended drought periods, punctuated by above average rainfall, characterised by extreme high rainfall events. For the Swan galaxias, a small freshwater fish that inhabits isolated upland streams in this area, the impacts of climate change, in conjunction with the ongoing threat posed by invasive fishes, suggest the outlook for Swan galaxias is perilous. Long term monitoring highlights the effects of climate change for the species. Previous efforts to translocate the species has had mixed success but the extremes of drought and flood are now impacting on the most robust populations. The requirement to seek translocation sites that negate the threat posed by climate change is paramount if the species is to survive.

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Past and future shifts in distribution and temporal persistence of kingfish (*Seriola lalandi*) oceanographic habitat in southeast Australia

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2. *CSIRO Oceans and Atmosphere, Hobart, Tasmania*

Climate-driven shifts in species distributions are occurring rapidly within marine systems and are predicted to continue under climate change. This study modelled oceanographic habitat suitability for kingfish (*Seriola lalandi*) from southeast Australia using multiple environmental variables at monthly time-steps from 1996 to 2040. Habitat predictions were used to: 1. estimate rates of spatial change in the core and poleward edge of suitable oceanographic habitat for kingfish, and 2. assess for changes in the temporal persistence (months per year) of suitable oceanographic habitat within six coastal bioregions through time. Rapid climate-driven poleward shifts in core (94.4 km decade⁻¹) and poleward range edge habitats (112.9 km decade⁻¹) were found to have already occurred. A decline in temporal habitat persistence is predicted in the future for the northernmost (equatorward) bioregion assessed, while increases are predicted for the three southernmost (poleward) bioregions. We suggest that temporal habitat persistence is an important metric for climate change adaptation because it provides fishery-relevant information. Our methods demonstrate how novel metrics relevant to climate adaptation can be derived from predictions of species' environmental habitats, and are appropriate for the management of fisheries resources and protection of high conservation value species under near-future climate change.

Target 1 Million Getting More Victorians Fishing

Travis Dowling¹

1. Victorian Fisheries Authority, Queenscliff, VIC, Australia

Recreational fishing provides significant economic and social benefits. In Victoria, it is estimated that over 830,000 people go fishing every year and this generates \$2.6 billion in direct output.

The Victorian State Government is committed to growing recreational fishing participation by delivering its \$46 million Target One Million plan, which aims to grow participation to one million anglers by 2020.

The Target One Million plan is comprised of 19 commitments and is supported by fisheries management, science, aquaculture, compliance, education and social connection to ensure the sustainability and vibrancy of Victorian recreational fisheries.

Key highlights Target One Million and recreational fisheries management in Victoria include:

- Removal of commercial netting from Port Phillip Bay
- Establishing of the Women in Recreational Fishing Network
- Delivering school education and children's fishing events and festivals
- Opening of Trout cod fisheries at Beechworth
- Stocking Hazelwood Pondage with barramundi
- Saving Lake Toolondo, one of Victoria premier trout fisheries
- Stocking Rocklands Reservoir to create a native fishery
- Improving access by removing boating restrictions at Blue Rock Lake
- Opening Dartmouth Pondage to fishing
- Developing the GoFishVic smart phone app for better recreational fishing monitoring
- Establishing the Wild Trout Fisheries Management Program
- Developing a rock lobster app to measure recreational catch
- Phasing out of opera house nets and establishing Yabby Net Swap program
- Conferences to better engage and build capacity of recreational fishers

Citizen science provides insight into Mulloway life history

Lauren Veale¹

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Citizen science has provided an effective way of advancing our knowledge on Mulloway. Funded by Victorian Recreational Fishing License Fees, the research began in late 2014 and has seen over 700 frames donated by more than 150 anglers. Donated samples, together with a small number of scientifically collected Mulloway, range in total length from 51 to 170 cm and have been aged between 3 and 25 years. Age structure information reveals the species exhibits naturally variable recruitment, with a dominant cohort corresponding to strong recruitment in 2011. The majority of Mulloway (90%) have been caught from estuaries where individuals have predominantly been ≤ 85 cm and $\leq 6+$ years, corresponding to the approximate estimate of 50% maturity. The high abundance of juveniles in Victorian estuaries highlights the importance of these systems as nursery areas. Important genetic analyses reveal that Mulloway from the Coorong across to Westernport Bay, form one distinct subpopulation. Improved information on species biology and stock structures presents a timely opportunity to reassess the current management regulations for Mulloway in Victoria. The partnership with recreational fishers is also providing insight into Mulloway movement patterns across Victoria and South East SA through a new external tagging program.

Informing sustainable management of Victoria's wild catch recreational fisheries.

Simon D Conron¹

1. *Victorian Fisheries Authority, Queenscliff, VIC, Australia*

The Victorian Fisheries Authority recognised in the 1990s that with increasing population growth and increasing popularity of recreational fishing there was a need to include recreational fishery data into fish stocks assessments, and to ensure these assessments had relevance to recreational fishing. Consequently, angler-based monitoring programs were developed and implemented. This presentation is focused on describing the approach taken to provide monitoring data for Victoria's largest fisheries where highly targeted species such as snapper, King George whiting, sand flathead and black bream require ongoing assessment. Creel surveys can be a cost effective way to assess changes in the fishery and to ensure reliable data is used to inform management stock status decision making. For regional areas of the state and for lower value and lower risk fisheries, such as black bream in small estuaries, estuary perch, mullet and dusty flathead, more simplified and less expensive monitoring methods can be used such as an angler diary program. This presentation describes experiences of the pros, cons and pitfalls of these approaches.

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Victorian aboriginal fishing strategy actions and implementation

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2. *Victorian Fisheries Authority, Queenscliff, VIC, Australia*

The Victorian Government recognises that Aboriginal people have a strong connection to country that is central to their culture, both traditionally and today. Fishing is an integral part of the cultural and economic life of coastal and inland Aboriginal communities. All sites of cultural significance and artefacts are protected by the Aboriginal Heritage Act 2006.

The Victorian Fisheries Authority (VFA) is committed to working together with the Aboriginal community and other fishing sectors to sustainably manage fish resources in freshwater and saltwater country and Victorian fishery management plans recognise the importance of fisheries resources to Aboriginal communities. The VFA is evolving to incorporate the rights, interests, aspirations and culture of Aboriginal people into both what we do and how we work, in a way that also respects the interests of commercial and recreational fishers in accessing the community's fisheries resources.

The Victorian Aboriginal Fishing Strategy (2012) is focussed on achieving three key outcomes:

- Recognition of Aboriginal customary fishing rights for Recognised Traditional Owner Groups,
- Better economic opportunities for all Aboriginal people in fishing and related industries, and
- Sustainable fisheries management in collaboration with Traditional Owner Groups.

This presentation discusses the actions of the Strategy, and implementation.

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The use and influence of recreational fisheries data: importance of cohesion to confront uncertainty

Gary Jackson¹, Karina Ryan¹

1. *Sustainability & Biosecurity, Department of Primary Industries and Regional Development, North Beach, WA, Australia*

A range of scientific activities support recreational fishing, from providing advice for management regulations, sustainability and resource sharing, to evaluating enhancement from artificial reefs and stocking. Recreational data is obtained by sampling recreational fishers and from various of other research activities. Guiding principles for the use of recreational fisheries data can positively influence decision-making. These include recommendations to: 1) define clear objectives for survey designs and outputs; 2) choose designs with regard to quality, timeliness, costs and respondent burden; 3) conform with scientific principles and standard procedures for data collection and processing; 4) ensure data confidentiality and appropriate use; 5) present information according to scientific standards with associated uncertainty; 6) comment on erroneous interpretation and misuse; 7) ensure relevant data, design and outcomes are made publically available; 8) ensure cooperation among agencies to achieve consistency and efficiency; 9) adopt performance measures for meeting objectives to improve accountability; and 10) develop strategies for effective linkages between scientific advice and decision-making. Common principles for collecting and reporting recreational fisheries data can build trust among stakeholders and ensure appropriate and robust information is used to support evidence-based decision-making.

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Diel habitat use and movements of sooty grunter, *Hephaestus fuliginosus*, in a tropical Australian river, using radio and acoustic telemetry

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2. *Water Resources Division, Department of Environment and Natural Resources, Palmerston, NT, Australia*

The sooty grunter (*Hephaestus fuliginosus*) is an endemic freshwater species which is abundant in many rivers across the wet tropics region in Northern Australia. Despite its ecological, social and cultural importance, there is currently limited ecological knowledge of this species in terms of its habitat use and movements, which is required to provide detailed advice for establishing environmental flows. This study used radio and acoustic telemetry to examine the diel movement, meso-habitat use, and activity of sooty grunter in the Daly River system, Northern Territory. Analysis of 17 radio-tracked juveniles over a 10-day monitoring period found that juveniles had positive associations with riffle and run habitats both during the day and night, and tended to avoid pool habitats. Acoustic-tracking data from 16 sooty grunter over a 4-month period indicated strong site fidelity, with most fish using less than 2 km of the 34 km study reach. Within these areas, small-scale movements were undertaken at strikingly regular periodicity and activity was highest during the day. These findings indicate the importance of riffle and run habitats for this species. This information will contribute to better informed management of water resources in the Daly River and other northern Australian rivers.

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Movement and site fidelity of juvenile King George Whiting, *Sillaginodes punctatus*, in Victoria

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2. Victorian Fisheries Authority, Queenscliff, VIC, Australia

The movement of fish is an important consideration in the management of fishery species. King George Whiting is a key species of recreational and commercial importance in Victoria where the fishery is based on juveniles in the three major bays. The fishery targets fish of approximately 2 to 4 years of age, with older fish moving out of the bays onto the open coast. We used otolith microchemistry to determine whether juvenile whiting moved between bays in their first two years of life. Post-settlement chemical signatures in otoliths from 2+ age Whiting in the bays were significantly different, showing that juveniles up to that age were not mixing between nursery bays. A current project where recreational fishers are tagging 2- to 4-year-old Whiting has resulted in a relatively high recapture rate (7%) and recaptures have all been very close to the tagging location after up to a year at liberty. The results indicate that older Whiting are site attached or show site fidelity where movement may occur but individuals tend to return to a location on a regular basis. The results have implications for fishery management in relation to the spatial scale of management and the possibility of localised depletion.

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The movement of mulloway (*Argyrosomus japonicus*) around the Great Australian Bight Marine Park inferred from satellite telemetry

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Very little information is available on the movement ecology of predatory demersal fish. This is concerning as many demersal fish species provide important ecosystem services and support significant commercial and recreational fisheries. Consequently, improved information on movement of these species has the potential to underpin more informed environmental and resource management outcomes. Implementation of marine protected areas (MPAs) is increasingly being used as a management tool and has the potential to enhance the sustainability of demersal fish populations. Mulloway (*Argyrosomus japonicus*) is a fish species that could potentially benefit from MPAs as there are concerns that they may be declining in some areas. Although this is an iconic species, little is known about their movements. During the Austral summers and autumns from 2011 to 2014 we deployed 19 pop-up satellite archival tags (PSATs) on mature mulloway at an aggregation site in the Great Australian Bight Marine Park (GABMP), with the main objective to examine their movement patterns. Approximately 58% of the tags transmitted useful data. Pop-up location data revealed that the fish moved up to ~550km from the tagging location. The acquisition of movement information will support decision making for management of this important species.

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Are coral reefs important to epipelagic sunfish?

Marianne Nyegaard¹

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The strange and impressively large ocean sunfishes have traditionally been considered to be solitary giants, drifting passively in ocean currents. Tagging studies have revealed the opposite – sunfish are active epipelagic hunters, diving deep for their meals. However, the epipelagic is not the only habitat these giants utilise. Seasonally, bump-head sunfish *Mola alexandrini* are seen on the shallow coral reefs (<40 m) off Nusa Penida near Bali, Indonesia, where they seek cleaner-fish interactions. The increasing tourist dive pressure on the sunfishes is of growing concern, however a paucity of understanding of this seasonal phenomenon prevents a meaningful impact assessment. In this study we examine the sunfish seasonality off Nusa Penida, the potential importance to the sunfish of the relatively limited Nusa Penida reef systems, as well as if the Nusa Penida Marine Protected Area offers a meaningful framework for regulating sunfish tourism dive pressure. We achieved this by investigating sunfish movements off Nusa Penida through application of towed SPLASH tags, and by estimating sunfish encounter rates at different reef sections

based on > 4,000 tourist dives. The results indicate the biggest concern from the sunfish dive tourism may not be the sunfish, but rather the cleaner-fish habitat; the coral reefs.

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Quantifying fine scale movement of translocated freshwater catfish (*Tandanus tandanus*) in an inland river with acoustic telemetry

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2. Fisheries, NSW Department of Primary Industries, Grafton

3. Murray-Darling Freshwater Research Centre, La Trobe University, Wodonga

With increasing threats to freshwater biodiversity, translocation has become an important conservation strategy for managing fish populations. Understanding how translocated individuals respond to environmental variations in a new environment is vital to managing the translocated population. Acoustic telemetry has been widely utilized in studies involving broad-scale riverine fish movement and more recently, fine scale fish movement in marine environments. This technology may be a useful tool in riverine environments in quantifying fine-scale fish movements and the factors that affect them. We sourced 36 adult freshwater catfish (*Tandanus tandanus*) from a thriving population in a reservoir and four resident riverine fish, surgically implanted acoustic tags and released them in acoustic receiver arrays deployed in two nearby rivers. We monitored fish movement behaviour over a six-month period post-release. Fish movement behaviours did not significantly differ between the short and long-term. Differences in movement behaviour between release sites were interpreted with respect to river discharge and temperature at one site but not the other and population source had no effect on fish movement. Future work will continue to monitor long range movements of these fish to quantify similarities and differences in fine and broad scale movement responses to environmental variation.

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Effective management of fisheries using individual transferable catch quotas (ITQs) - time for a rethink

Kevin Rowling

Since the 1980s there has been a significant rise in the number of fisheries being managed by an annual Total Allowable Catch (TAC), often split among individual fishers as "Individual Transferable Catch Quotas" (ITQs). Australia is acknowledged as a world leader in this initiative and a number of fisheries, in both State and Commonwealth jurisdictions, are managed using ITQs.

Despite many documented successes for ITQ managed fisheries, a number of recent studies have raised concerns about the efficacy of management schemes based on ITQs. Multi-species fisheries with multiple gear types (and sometimes under multiple jurisdictions) are especially difficult. Unexpected and undesirable social outcomes have also been reported for some fisheries as a result of the implementation of ITQs.

The success of ITQ-based schemes in achieving management objectives was reviewed for a number of Australian fisheries, including the complex South East Fishery. The results show a wide range of outcomes, suggesting that ITQs are not the panacea for management of all types of fisheries. Alternative management approaches involving the collection of adequate biological data and the robust application of standard fishery management practices are suggested. The challenge will be to resist the pervasive economic justification for ITQ management.

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Assessment of non-recovery and under-caught TAC species within the adaptive management framework

Nastaran Mazloumi, Simon Nicol

Fishery performance is highly dynamic and depends on several environmental and non-environmental parameters such as changing temperature and ocean currents, fish behaviour, changing market and economic conditions. Therefore, management tactics ideally should be designed to be adaptive to respond to changing conditions. A robust adaptive and flexible management strategy identifies and measures appropriate indicators against their relevant reference points that trigger management interventions. Indicators can be model-based quantities where adequate data on life history stages, stock biomass status and fishing mortality are available or model-free indicators such as CPUE trends and proportion of catch in particular life stage. Slow recovery or lack of recovery of a number of overfished stocks in Australia's Commonwealth fisheries and the continual decline in catch for some quota species, despite significant management interventions, has raised concerns that the traditional fisheries indicators we have applied to inform management may not be as responsive and robust as first envisaged or measuring the entity of interest. Our current study aims to evaluate the efficiency of possible indicators explaining the fisheries stock performance within the adaptive management strategy framework.

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Managing recovery of abalone stocks from a catastrophic environmental event

Harry Gorfine¹, Kate Simpson¹, Toby Jeavons¹

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Value for money - optimising survey design in a budget constrained fishery research program

Katherine Heldt¹, Stephen Mayfield²

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2. SARDI, Adelaide, SA, Australia

Fishery managers rely on species information, such as abundance and biomass, to optimise harvest strategies and establish suitable total allowable commercial catch. In fisheries that lack data from commercial operators, fishery-independent data can underpin assessments and inform management decisions. However, field-sampling programs are costly and require appropriate design to avoid obtaining biased data. In Coffin Bay, SA, the 50 t Vongole Fishery (*Katelaysia* spp.) contains four primary fishing grounds and uses fishery-independent surveys to determine harvestable biomass and exploitation rate (i.e. catches at or below 7.5% of biomass estimates). Recent budget constraints resulted in implementation of a triennial sub-sampling program whereby at least one primary fishing ground is sampled annually on a rotational basis with spot sampling occurring outside the main area (N=124–149 transects). Investigations of 2015 survey data, which reflect complete sampling of all fishing grounds (N=223), showed that the triennial sampling program biased exploitation rates by -1.4% to 19.8%. Furthermore, random selection of 25%, 50% and 75% of data resulted in high variation among biomass estimates for *K. rhytiphora* but not *K. scalarina*. By understanding the impacts of sampling programs on biomass estimates, survey designs can be optimised to produce the best possible biomass estimates within budget constraints.

Prioritising species for fisheries research: a decision analysis approach for diverse fisheries of low financial value

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1. NSW DPI Fisheries, Mosman

2. NSW DPI Fisheries, Coffs Harbour

3. NSW DPI Fisheries, Port Stephens

Methods to assess and manage fisheries have developed considerably over the past three decades; however, their uptake has been restricted due to limited resources in many regions. A key issue for assessing and managing resource-limited fisheries is prioritisation of species and other ecosystem components. We developed a participatory MCDA approach to prioritise species for research in New South Wales, Australia, based on their importance to fisheries management. The approach: (1) structures the decision problem, (2) forces consideration of management objectives at a species level, (3) handles the complex trade-offs generated by multiple fisheries objectives, and (4) balances differences in the perceived importance of management objectives among fisheries managers. Performance scores and attribute weightings for ten management objectives were elicited from two groups of managers focusing on either the commercial or recreational fishing sectors. These values were then used to generate total performance scores for 141 species following Multi-Attribute Value Theory (MAVT). The ordered list facilitates decisions regarding the optimal allocation of limited resources for research in the State. Our approach can be adapted to fisheries in other regions and expanded to include additional ecosystem components.

Determining stock status in a complex, benthic-invertebrate fishery: Accounting for the impact of spatial, temporal and fleet dynamics

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1. SARDI, West Beach

2. SARDI, Port Lincoln

Abalone stocks support valuable fisheries across southern Australia. Two target species – greenlip (*Haliotis laevigata*) and blacklip (*H. rubra*) – form large numbers of stocks across their range, but for pragmatism stock status determination is required at a larger spatial scale (e.g. three zones across South Australia). Assigning zone status is complicated by several factors, including individual stocks likely being at different levels of exploitation and risk of overfishing. This is partly due to abalone being hand-harvested through diving by a small but highly mobile fleet, with fishing location driven by numerous factors including weather, market preference for particular abalone, convenience and abalone abundance. Fleet dynamics also pose challenges

for catch rate estimation – a key performance indicator – because it can undermine the link between catch rate and abundance. For example, catch rates can change with the proportion of the target species in the catch, remain high with declining abundance (hyperstability), or be depressed by new entrants (hyperdepletion). Using a greenlip abalone fishery as an example, this study shows how these complexities can be overcome and proposes an approach to determining zonal stock status through accounting for catch rate uncertainty, fleet dynamics and variable levels of depletion among stocks.

Climate induced coral bleaching and consequences for coral reef habitats and fish assemblages

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Climate change is now the foremost threat to coral reefs, following unprecedented recurrent years of mass coral bleaching on Australia's Great Barrier and many other reef locations. Climate impacts are however, occurring against a backdrop of other perennial disturbances and stresses, and these cumulative pressures are causing sustained and ongoing degradation of coral reef environments throughout the world. Also, despite the emergence of direct environmental impacts on the distribution and performance of reef fishes, habitat degradation (including coral loss and topographical collapse) represents the first and foremost threat to coral reef fishes posed by global climate change. Moreover, degradation of reef habitats reduces the capacity for fishes to mediate exposure to changing environmental conditions, making them even more vulnerable to climate impacts. There are very few species that actually benefit from climate-induced changes in environmental conditions and habitat structure and their increases in abundance does not compensate for extensive declines in abundance across a large proportion of reef fish species. Ongoing climate change and mass coral bleaching will therefore, have major deleterious impacts on the biodiversity, productivity, structure and function of reef fish assemblages, and the only way to minimise these impacts is to reduce global carbon emissions.

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Exploring the direct and indirect effects of warming on fish growth

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Estuaries are productive dynamic systems that sustain a variety of important recreational and commercially fished species. Climate change will result in the physical environment of estuaries changing due to altered rainfall patterns, evaporation rates, and thermal regimes. Physical changes to the environment will affect the biology of all species within estuaries by directly affecting fish physiology, resultant energy budgets, and hence growth. Environmental changes may also indirectly impact estuarine fish through altered food webs, such as via temperature affecting phytoplankton densities that subsequently impact the abundance of first order consumers which become prey for higher order predators. Shifts in prey availability and changes in food web composition will alter predation and competition regimes, and in turn result in an indirect effect on estuarine fish growth. My research tests for the importance of direct (temperature) and indirect (food availability) effects on the growth of juvenile black bream (*Acanthopagrus butcheri*). Preliminary results show that a key amphipod prey species is directly affected by warming. However, black bream appear resilient in the face of direct temperature changes, and instead their growth primarily responds to food availability. This potentially reflects an indirect response to warming and will be explored further in my presentation.

Exploring the impacts of a climate change double-header: do rising temperatures impact hypoxia tolerance in estuarine fish?

Julia Brueggeman¹, Kathryn Hassell¹, John Morrongiello¹

1. University of Melbourne, University Of Melbourne, VIC, Australia

Estuaries are one of the most vulnerable and degraded environments on Earth. They are impacted by anthropogenic stressors, including pollution and run-off from storm-water that alters natural chemistry and productivity. The latter can impact dissolved oxygen levels. Layered on top of anthropogenic pressures is climate change. Reduced rainfall means less freshwater input and increased stratification. A hotter climate means warmer waters, which have a reduced capacity to store dissolved oxygen. Together, the impacts of anthropogenic stressors and climate change increase the risk of estuarine fish experiencing hypoxia. Ample oxygen is crucial for fish health and reproduction.

My study assesses how the combined effects of increasing temperature and reduced dissolved oxygen affect Eastern blue-spot gobies from populations varying in proximity to urbanization. Fish were housed at 1 of 3 temperatures (15°C, 20°C, and 25°C), placed in respirometers, and exposed to declining levels of O₂ (80% to 10%). Metabolic performance and critical PO₂ of each fish was measured and compared across a heavily urbanized and a natural population. I will discuss my results in light of the combined threat that climate change and urbanization pose for estuaries, and explore whether long-term hypoxic exposure confers greater resistance to these conditions in the future.

Tropical fish incursions in temperate Australia: do patterns reveal a climate-change signal?

David DJ Booth¹

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An 18-year monitoring dataset indicates high interannual, interspecific and spatial variation in influx and persistence of coral-reef fishes into SE Australia. Links to key physical variables are unclear but there are exceptions. I will discuss how the relative role of offshore processes (eg EAC patterns) vs receiving environment (e.g. local habitat, species, winter temperatures and climate-related storm events) differ among key fish taxa.

Baby fish in hot water – what are the long-term effects on performance?

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2. *Environmental Epigenetic Program, Division of Biological and Environmental Sciences, King Abdullah University of Science and Technology, Thuwal, Kingdom of Saudi Arabia*

Sea surface temperatures are projected to rise by 1 to 3°C by the end of the century. On some tropical reefs, summer thermal anomalies presently cause end-of-century temperatures, for days even weeks at a time. Detrimental effects of projected future warming on the behaviour, physiology, and morphology of adult reef fishes have been observed. Here, we tested if the length of exposure to elevated temperature during early development influences the resulting phenotype in the Spiny damselfish, *Acanthochromis polyacanthus*. Newly hatched offspring from wild-caught pairs were reared for 15 weeks at the average summer sea temperature for the collection location (present-day control) and in four treatments, where they were exposed to a higher temperature (+2°C) for the first 3, 7, or 30 days' post hatching, or for the entire 15 weeks. We compared body size, burst-swimming responses, critical thermal limits and patterns of sex determination. The results demonstrate that short-term summer thermal anomalies might not have long-term effects on juvenile performance. This has important implications for understanding how the increasing frequency of summer thermal anomalies, such as those recently experienced by the Great Barrier Reef, will affect the ability of reef fish to respond to rising ocean temperatures.

GoFishVic – The new Victorian Angler Diary App for recreational fishery monitoring and engagement

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1. *Victorian Fisheries Authority, Queenscliff, VIC, Australia*

Recreational fisheries are numerous and diverse, therefore their management can often occur in a data-poor environment.

Use of technology such as smart phones and apps provide new opportunities to establish innovative monitoring programs to improve fisheries management and recreational fishing.

Angler diary smart phone 'apps' are being trialled worldwide and show promise as a cost-effective and angler engaging method of collecting valuable recreational fishing catch and effort data.

Under the Victorian Government's Target One Million Plan to improve recreational fishing, the Victorian Angler Diary Program is being expanded via creation of a smartphone app and the recruitment of avid anglers to record fishing data across the state's most popular waters.

Benefits of the app will include:

- More informed fisheries management decision making (through stocking, regulations, habitat rehabilitation, flows etc.).
- Improved angler fishing success through users recalling their fishing catch trends against time, technique and environmental variables.
- Engagement and networking opportunities through fishing metrics, angling competitions, and sharing fishing experiences with other users.
- Building of recreational fishery performance data time-series for the development of recreational fishery harvest strategies.

This presentation provides an overview of the Victorian Angler Diary Program App – *GoFishVic* - three months following release.

Recreational survey design to assess biological characteristics in recreational fisheries

Cameron J Desfosses¹, Karina L Ryan¹, Fabian I Trinnie¹, Norman G Hall¹

Recognition of the importance of recreational fisheries requires an appropriate survey design to collect data that is representative of the catch. This study describes a probability-based, access-point survey to collect biological data from catches of western rock lobster (*Panulirus cygnus*) retained by boat-based recreational fishers in Western Australia, involving substantial spatiotemporal differences across the distribution of the species and recreational fishery. Carapace length and body weight were recorded for retained lobsters at fifteen latitudinally-separated boat ramps across three fishing seasons (2015/16-2017/18). The spatiotemporal scope of the survey differed between years to determine a long-term, cost-effective design to evaluate the mean body weight of retained lobsters. Current funding allows for six (3 weekday/weekend) to eight (4 weekday/weekend) shifts per site per month. Confidence intervals (95%) for bootstrapped mean body weight did not differ between spatial and temporal subsets of data. This provided strong evidence that future monitoring of the mean body weight of *P. cygnus* retained by recreational fishers in WA can coincide with sites and months with greatest fishing activity. This facilitated a cost-effective annual survey, with a recommendation to conduct occasional, comprehensive, probability-based surveys to detect longer-term biological changes. This approach could be applied in other low-participation recreational fisheries.

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Victorian recreational rock lobster tagging program

Toby Jeavons

The Rock Lobster Fishery is Victoria's most valuable fishery. Southern Rock Lobster are a prized catch among recreational divers and have a commercial landed catch value of \$25 million per annum. Whilst the commercial catch is quota managed, it was recognised that there was a lack of information on rock lobster numbers harvested by the recreational sector. This information is needed to work towards accounting for total mortality of rock lobster to effectively manage the fishery and ensure ongoing access to all sectors.

On 1 July 2017 the Victorian Fisheries Authority implemented a 3-year tagging trial program where all recreationally caught rock lobster are required to be tagged and reported via an online app. The number of tags used each year represents the number of rock lobsters that are removed by the recreational sector from the stock in that year.

This discussion will focus on the collaboration between science and management, and the success and learnings from the first 16 months of the 3-year trial program to quantify the recreational take of rock lobster in Victoria.

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Rebuilding rock lobster stocks on the east coast of Tasmania: challenges of managing recreational and commercial sectors

Jeremy Lyle¹, Klaas Hartmann¹, Justin Rizzari¹, Satoshi Yamazaki¹, Mary McKay¹

1. University of Tasmania, Hobart, TAS, Australia

Rock lobster stocks off eastern Tasmania are in a depleted state and modelling indicates that catches must be reduced to facilitate recovery. A 10-year stock rebuilding strategy, underpinned by a catch cap for the commercial sector and a catch share for the recreational sector, was implemented in 2013. While the commercial catch can be monitored and controlled directly, management of recreational catches is more problematic. In an effort to restrict recreational catches there have been drastic reductions in bag and possession limits and a progressive reduction in the season length. High and varying levels of participation, however, make management of recreational catches difficult, a situation likely to be further exacerbated as stocks rebuild. For the commercial sector, the catch cap represents a competitive catch quota that, as catch rates improve, is likely to influence fleet dynamics as fishers race to take the catch limit.

Understanding relationships between fisher behaviour, their expectations/aspirations, response to changes in stock status and management intervention is critical when implementing effective management. This study addresses the practical challenges of achieving the stock rebuilding objective by providing options to assist managers and fishers in achieving the ecological, social and economic goals for the fishery.

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Mako shark movements and habitat use in the southwest Pacific Ocean

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Shortfin mako sharks (*Isurus oxyrinchus*) are pelagic predators in the open ocean and coastal waters. They are frequently caught in tuna longline fisheries but the impact of fishing is largely unknown. Mako sharks are believed to be highly mobile migrators, but little is known about how they use their habitat. Electronic tags are now shedding light on the horizontal and vertical movement patterns of mako sharks. Satellite tagging in New Zealand has revealed that juvenile mako sharks are much more resident than previously realised, inhabiting coastal waters for periods of several months. There is a general movement to warmer waters north of New Zealand in winter, with larger sharks moving further. Some sharks have travelled as far as Australia, Vanuatu, Fiji and French Polynesia. Foraging occurs mostly in coastal waters over the continental shelf, and sharks tend to move rapidly and often in near-straight lines while in the open ocean. Most of their time is spent in the upper 100 m of the water column but deep dives during the day are common, with depths sometimes exceeding 600 m. The relatively small-scale movements of small juvenile mako sharks suggest that management of bycatch needs to be at a regional scale.

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Latitudinal variation in the growth and movement patterns of east-coast Snapper (*Chrysophrys auratus*).

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Tagging data spanning 30 years from approximately 25,000 Snapper (*Chrysophrys auratus*) from Queensland and New South Wales were collated, and recapture data analysed for patterns in growth rates and movements. Snapper along eastern Australia exhibited significant variation in growth rates, with Snapper growing faster in more northern latitudes. Patterns of recaptures demonstrated that the majority of Snapper did not move substantially from their locations of tagging; however some individuals moved considerable distances with 10 fish being recaptured more than 500 km from where they were tagged. The results are discussed in terms of assessment and management of the east-coast Snapper stock.

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Insights into the juvenile dispersal of east Australian tailor using a particle tracking model

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Annual migrations occur in many coastal species. These migrations are often accompanied by spawning events which result in larvae and juveniles being transported along the coast by boundary currents. Patterns in larval transport of coastal species have important implications for species connectivity, conservation, and fisheries, especially in the vicinity of a strengthening boundary current such as the East Australian Current. This study used year round surveys from the entire range of east Australian tailor (*Pomatomus saltatrix*) to identify an extended spawning period which extends into previously unrecognised spawning locations in northern NSW. Generalised Additive Models were used to identify the environmental drivers of spawning and create a predictive model of when and where spawning occurs. Combined with fecundity estimates, a particle tracking model was developed to better understand the dispersal of larvae and juveniles from the spawning grounds before they settle in estuaries up to 12° of latitude away. This study highlights the importance of both larval dispersal and reproductive biology for understanding connectivity across a species' range.

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Migration ecology of pouched lamprey, *Geotria australis*, in the River Murray, Australia

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Management and conservation of migratory fish requires an understanding of species-specific movement ecology. For the anadromous pouched lamprey (*Geotria australis*), details of upstream spawning migrations remain poorly understood. We used acoustic telemetry and passive integrated transponder (PIT) tags to investigate upstream spawning migrations of pouched lamprey captured near the mouth of the River Murray, Australia, across two migration seasons. The majority (90%) of acoustically tagged individuals exhibited movements into the lower River Murray, whilst 10% were detected entering local tributaries. Unfortunately, individuals tagged with acoustic transmitters suffered high rates of mortality from capture in commercial fishing nets <100 km upstream of release locations, due to the external tagging technique adopted. Of lamprey that were PIT tagged only, ~55% were detected on fishway PIT readers on the River Murray 274–878 km upstream of release locations. Migration was predominantly nocturnal, and rates of migration between detections at fishways were at times rapid (up to 47 km.d⁻¹), but varied among river reaches. We conclude that contemporary upstream migrations of pouched lamprey in the River Murray may be long-distance and have been supported by the recent construction of multiple fishways. The end-point of these migrations, including spawning sites, remains the subject of ongoing research.

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Can collective memories shape herring distributions? A test, linking space-time models and population demographics

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Social learning can be fundamental to cohesive group living, and for many schooling fishes, inter-generational information transfer is considered a vital ingredient underpinning movement decisions. Yet key information is often missing on the spatial outcomes of such decisions, and the collective's role in shaping migratory traditions remains uncertain. To explore these issues, we focused on Atlantic herring (*Clupea harengus*), a long-lived, dense-schooling species, noted for its unpredictable shifts in winter distribution, and developed space-time regression models of wintering dynamics around Iceland over 23 years. We included covariates reflecting local-scale environmental factors, recent fishing activity, and two proxies for spatial 'memory' of past wintering sites. The previous winter's occurrence pattern was a strong predictor of the present pattern, its influence increasing with adult population size. We propose that a 'wisdom of the crowd' dynamic may be operating, by which navigational accuracy improves in larger, better synchronized schools. Wintering herring also preferred warmer, fresher waters, close to hotspots of summer zooplankton biomass, our results indicative of heightened environmental sensitivity in younger cohorts. Predictions one-year ahead illustrate the value of uniting demographic information and non-stationary models to quantify the strength of collective memory in animal groups, and its relevance for spatial management directives.

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Migration to freshwater increases fitness in a partially diadromous fish

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Diadromy is a remarkable form of migration where individuals undergo regular movements between fresh and marine waters for the purposes of feeding and reproduction. Diadromy occurs in many taxa and can take various forms (*catadromy*, *anadromy* and *amphidromy*). Despite having arisen in many independent lineages of fish, molluscs and crustaceans, the evolutionary drivers of diadromous migration remain debated. Here, I will present a novel test of the often-cited productivity hypothesis. This theory predicts that diadromy will occur at an evolutionary mid-point as species transition between entirely marine and freshwater lifecycles, due to a primary productivity differential between marine and freshwater habitats. Otolith chemistry and biochronology data are analysed in a partially catadromous fish (barramundi *Lates calcarifer*) to determine the effect of diadromy on growth. On average, individuals that accessed fresh water grew ~25% faster than estuarine residents in the year following migration, suggesting that catadromy elicits a fitness advantage over non-catadromous life-histories (i.e. barramundi that remain in the estuary), as predicted by the productivity hypothesis. We argue, however, that temporal and ontogenetic fluctuations in relative reproductive success stabilise selection on differing migratory phenotypes.

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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.

A mean rate estimation method for Poisson Count Data with Heterogeneous Exposure: Application to bycatch risk assessment

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Ranking can support risk management by prioritising entities of interest based on rates of relevant events, such as bycatch rates for fleets, failure rates of targeting species, or catch rates across different fisheries. We consider the situation where the entities exposure to risk is heterogeneous as might arise when, for example, number of fishing trips varies between fleets, or fishing effort varies between different fleets. We develop an empirical Bayes inference method (a two stage hierarchical model) for the estimation of event rates. We demonstrate an application of the proposed method for seabird bycatch data comprising the varying efforts for a pool of fleets over a given time horizon. We show how our empirical Bayes inference for the rates of Poisson count data can provide management insights about the worst and best performing fleets in terms of bycatch.

Enriched stable isotope marking of hatchery trout via immersion: A method to monitor restocking success.

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Hatcheries release millions of juvenile trout into rivers and lakes annually with little or no post release monitoring. This is, in part, because marking of hatchery-reared trout is often not compulsory and currently available marking methods are either considered costly, cause high mortality, inconvenient to apply, or have poor long-term retention rates. Here, we test a stable isotope larval immersion marking technique to determine if a suitable low cost, easy to apply fish friendly marking method could be achieved for brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss*. Larval immersion using 100 µg L⁻¹ of 137Ba and 136Ba over a 24 hr period returned a 100% mark-success rate for both brown and rainbow trout, at a marking cost of approximately \$US 0.004 per fish. Barium isotope ratios detected in the otoliths of marked fish were 11 times greater than ratios measured in control fish. The process of marking was easy to apply, with < 0.5% mortality during the marking process. We conclude that larval immersion marking is a suitable method for long-term monitoring of released hatchery-reared trout. If adopted, the method would enable hatcheries to cost effectively and accurately assess the long-term contribution of restocked fish to wild populations

Measuring congruence between electronic monitoring and logbook data in three Australian Commonwealth longline and gillnet fisheries

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Electronic monitoring (EM) technologies have the capacity to collect fisheries-dependent data to support decision-making. Following successful pilot studies, EM was introduced in three Australian Commonwealth-managed fisheries in 2015: the Eastern Tuna and Billfish Fishery (ETBF); the Western Tuna and Billfish Fishery (WTBF) and; the Gillnet, Hook and Trap (GHAT) sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF). For each fishery, we compared the reported catch of retained and discarded species, and interactions with protected species, between fisher logbooks and EM. Congruence between logbook and EM data for retained and discarded catch was higher in the ETBF and WTBF compared to the GHAT sector, although there was significant variation among species groups (e.g. target, byproduct and bycatch) and individual species. Congruence was high for some species (mainly target retained) but for others (mainly non-target discarded) there were clear taxonomic and reporting issues, which reduced congruence. Congruence for protected species interactions was higher in the GHAT than in both the ETBF and WTBF. This may reflect a greater emphasis on improving protected species reporting in the GHAT compared to the other fisheries, or simply a result of superior camera placement and crew operational procedures for releasing protected species.

Changes in logbook reporting following the implementation of electronic monitoring technologies in Australian Commonwealth fisheries

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In Australia, electronic monitoring (EM) was implemented by the Australian Fisheries Management Authority (AFMA) in three of its managed fisheries: the Eastern Tuna and Billfish Fishery (ETBF), Western Tuna and Billfish Fishery (WTBF) and Gillnet Hook and Trap (GHAT) sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF) from 1 July 2015. We examine logbook data from the first two years of EM operation, with the aim to measure the effect of the AFMA EM program on fisher

logbook reporting. During this period, while there was no change in logbook reporting of retained target species catch, there was an increase in the reporting of discarded target species catch in all three fisheries, an increase in logbook reporting of non-target discard species in the ETBF and an increase in logbook reporting of protected species interactions in all three fisheries. Observed changes could be due to differences in gear selectivity, perceived legitimacy of EM among industry, and/or underlying management incentives. It is important that AFMA's EM program is regularly reviewed to inform not only its own development but that of other nations or organisations considering EM as a potential replacement or supplement to other fishery-dependent data collection tools.

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fishIDER – A bilingual, web-based fish identification tool for market fish in Indonesia

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Accurate species identification is a fundamental requirement for fisheries research and management. Fisheries assessments routinely rely on fish catch data recorded by port-based enumerators and/or on board observers. The quality of these assessments can be significantly impacted by data that is flawed as a result of incorrectly identified species. In Indonesia, training workshops have identified an inadequate level of identification skills of some fisheries staff, especially for fish that are in 'less-than-fresh' condition, as commonly seen in markets. Improving identification skills has been listed as a high priority objective by fisheries management organisations. The need for a resource to train and assist fisheries staff in confidently identifying fish has resulted in the development of *fishIDER* - fish Identification Database and Educational Resource. *fishIDER* is a web based, bilingual fish identification training tool, and has been developed with the primary aim of improving the identification skills of fisheries staff of fish in market situations. This talk will include a demonstration of *fishIDER* and a discussion of its future development.

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The wet bits: locating potential freshwater fish refuges in small, unregulated Victorian streams

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Refuges are important to the survival and persistence of aquatic organisms in drier landscapes and are particularly important during periods of seasonal or supra-seasonal drought. Natural instream refuges are primarily groundwater dependent, particularly those with medium to long-term persistence. The effective and sustainable management of important aquatic refuge habitat in groundwater dependent ecosystems (GDEs) in Victoria requires knowledge of their distribution, condition and environmental values. Current knowledge on tributary GDEs in Victoria is variable and generally poor, particularly those in unregulated streams in mid to upland areas of catchments. Improved knowledge of these aquatic refuges across the landscape is critical to inform effective management to improve the resistance and resilience of important aquatic populations, species, and ecological communities, particularly under future climate change scenarios. We investigated whether available remote sensing imagery/coarse spatial data could be used to predict the location of riverine GDEs at the local scale (subcatchment/tributary) in unregulated systems, and developed a rapid methodology, as a first step, for the identification of GDEs potentially important as refuges for drought sensitive aquatic fauna.

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Schyzocotyle acheilognathi (Asian fish tapeworm) found in goldfish (*Carassius auratus*) and carp (*Cyprinus carpio*) in Western Australia

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Alien parasites introduced via invasive fish species (co-invaders) pose one of the most important threats to freshwater fishes throughout the world. Two of the most invasive fish species in Australia are *Cyprinus carpio* (common carp) and *Carassius auratus* (goldfish). In February, 2018, as part of a feral fish control program, 65 goldfish and koi carp were removed from a lake in Perth, Western Australia. Fish intestines/stomachs were screened for parasites by microscopy and molecular tools, as part of ongoing PhD research on *Giardia* and *Cryptosporidium*. Analysis revealed that 12.31% of the fish (6 carp and 2 goldfish) were parasitized with large numbers of intestinal worms. Microscopic and molecular evidence confirmed the species to be the Asian fish tapeworm (*Schyzocotyle* (= *Bothriocephalus*) *acheilognathi*). This is the first report of this parasite in Western Australia. The parasite has a wide host range, is highly pathogenic and frequently causes mortalities, which raises major concerns for the unique and threatened native freshwater fishes of the region.

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Tilapia: To eat or not to eat? Policy vs public perspectives in invasive species management

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African cichlids Mozambique tilapia (*Oreochromis mossambicus*) and spotted tilapia (*Tilapia mariae*) were illegally introduced to Queensland waters in the late 1970's. Shortly thereafter the state government legislated both species as 'noxious', and implemented a no-take approach to management that is still enforced today. *O. mossambicus* is now established in 24 of 76 catchments throughout the state, largely restricted to the east coast. *T. mariae* has established in only four northern Queensland catchments. There is evidence of tilapia naturally spreading across Queensland, although colonisation is generally slow. Most new tilapia infestations are the result of human-assisted translocations occurring via illegal stocking, live bait escapees or ornamental fish dumping. Notwithstanding, there is still a significant amount of native waterways in Queensland that remain tilapia-free. Given the growing number of infested catchments, there is increasing pressure from the public to change noxious fish policy to allow consumption of tilapia, citing heavier fishing pressure leading to a reduction in numbers. While contemporary science does not indicate this method effectively reduces invasive fish biomass, new regulatory requirements around community General Biosecurity Obligations (GBO) has brought about mounting public pressure for the government to review its current policies regarding the possession and consumption of tilapia.

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The grey list of noxious fish: time for an update?

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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. However, with an estimated population of 8.7 million pet fish and 1025 pet and aquarium shops, Australia is at risk of ornamental species establishing and impacting our native fauna. The significant ecosystem effects of translocated and non-native fishes, including carp and tilapia, is well known, reinforcing the movement to identify the level of threat of non-established species as a primary step towards ensuring such species do not become established in the wild. Termed the "grey-list", these potentially noxious species were risk assessed by an initiative of an inter-governmental working group in 2010, with three reports published evaluating 806 species. This presentation re-visits the "grey-list" to both review the validity of the methods used and to update the background information, including assessing additional species. While the list has been an extremely important step in the fight against noxious species, initial analysis has found inconsistencies in the decision-making and methodology as well as the use of a precautionary principle that potentially overwhelmed the perceived threat level fish were attributed.

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Where do carp go in the Gunbower Forest during a flood?

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Gunbower Forest is an icon site and as such a watering strategy with multiple biodiversity benefits is implemented. However, along with these benefits there is also the detrimental impact that delivery of flows into Gunbower Forest also benefits the recruitment of carp. Apart from competing with native fish for resources, carp are also having impacts on the floodplain, especially in regard to native wetland vegetation. A Gunbower Forest carp movement study was undertaken to determine pathways of carp movement within the forest and for entry/exit locations between the forest and the river.

Forty carp were acoustically tagged in September 2016. Carp responded immediately to water inundation on the floodplain with some carp moving over large areas of the floodplain, whilst others showed limited floodplain movement. At least six entry/exit locations from the forest into the Murray River have been identified during the study. Several large river movement patterns were also observed, greater than 100 kilometres downstream and upstream. These fish moved away from a known carp breeding area during the spawning period, and returned after floodplain recession. Around a quarter of the tagged fish showed site fidelity, returning to their tagging location soon after the flood receded.

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The effectiveness of stream gradient as a natural ecosystem defender

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Increasing temperatures are allowing species globally to establish populations in previously inaccessible areas, potentially causing wide-ranging impacts on local ecosystems. Detecting natural dispersal barriers is therefore of enormous benefit to conservationists, who can prioritise areas more vulnerable to invasion. This is particularly useful in freshwater ecosystems, where there is often only one pathway between two given points. Here, we investigate the role of upstream slope and distance upstream as natural dispersal barriers to two fish species whose range in Scandinavia is shifting northwards, the northern pike (*Esox lucius*) and European perch (*Perca fluviatilis*). We used recolonisation of lakes that had previously contained both species before being

treated with the piscicide rotenone to measure species ability to disperse past natural barriers. Slope parameters of connecting streams were obtained using land terrain maps. We tested both species ability to disperse past short steep increments and longer uphill stretches. We found that whilst *E. lucius* were limited by longer uphill stretches of river, *P. fluviatilis* were limited by the distance between the lake and their source population. This will allow conservationists to prioritise efforts on lakes that are not protected by suitable downstream connections to source populations.

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Increasing knowledge of Victoria's growing recreational yellowtail kingfish fishery

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Yellowtail kingfish are a highly sought after recreational species due to their fighting ability and eating qualities. Historically (prior to 1990) kingfish were caught in several locations around Victoria; however since then, numbers have been in decline with targeted angler effort reducing concurrently. Since around 2010, reports of recreationally caught kingfish have increased considerably with a wide size range caught all along the coast. In Victoria, fundamental stock structure information was lacking in this developing fishery. This presentation reports on a project aimed at gaining intrinsic information such as genetic structure, growth, spawning characteristics, temperature preference using otolith microchemistry and trialling satellite tags to study kingfish movement. This information will be used to explore alternative management regimes that aim to grow the fishery into the future. The presentation will also discuss some of the advantages and disadvantages of engaging recreational anglers to supplement sample collection, as well as the extension of research results through different media streams.

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Carryover effects of early life growth on the survival of impoundment stocked fish.

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The environment experienced by a fish during its early hatchery life can profoundly affect its survival later in the wild. This is because individuals differ in key life history traits such as growth rate, which may increase or decrease their survival later in life. These traits can also be amplified by the environment, with consequences for entire populations. Understanding how an individual's early life affects long-term performance ('carryover effects') is particularly relevant for fish stocking, as millions of fish that have potentially variable growth are stocked into rivers and impoundments annually. While quantifying the effectiveness of fish stocking may be difficult, it is vitally important information for fisheries managers. This project addresses a fundamental gap in our understanding of what drives fish survival and subsequent stocking success, by exploring whether early life growth has lasting impacts on individual fitness in the wild. I will quantify the growth of individual fish that occurred in hatcheries prior to stocking into a range of impoundments, and then see how this influences the probability of survival after 6 months and 1 year. My results will provide critical information for managers to optimise hatchery practices to stock the fish with the highest chance of survival.

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Initial impacts of a harvest slot on Murray cod size structure and angler harvest in NSW

Nathan Miles

In an effort to improve size structure of Murray cod, *Maccullochella peelii*, size limits changed from a 600 mm minimum length limit, to a 550-750 mm harvest slot in 2014 across three states (NSW, Australian Capital Territory and Victoria). In order to better understand the initial effects of the regulatory change we examined Murray cod population characteristics in a section of the Murrumbidgee River over a 8 year period (4 year pre slot limit and 4 years post slot limit). We found some indication of truncation in length at the minimum sizes under both a minimum size limit and also under a harvest slot. It is therefore vital to continue monitoring Murray cod populations as they adjust to changing harvest restrictions, fishing effort, and environmental conditions. In this regard, the collection of time-series data should be regarded as essential for fisheries managers to understand changes within a fishery and the effectiveness of interventions.

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Trout drought: a transformational engagement strategy case study

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"The greatness of a community is most accurately measured by the compassionate actions of its members." Coretta Scott King
Effective engagement is a pivotal aspect of effective fisheries management, but engagement strategies are not always successful. We present a case study of trout fishery management to demonstrate how adopting a transformational engagement strategy has resulted in outcomes that were unattainable without the community support. A significant consequence is the empowerment of the angling community to take active leadership to manage solutions.

When old is new again. The use adult brown trout collected from spawning runs to supplement lake based fisheries.

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Since 1960, adult brown trout collected from spawning runs have been used to supplement some lake fisheries within Tasmania with poor or highly variable recruitment. This fisheries management strategy has at times, been favoured over hatchery stockings due to the highly variable returns resulting from fry or fingerling releases. However, following the closure of the primary trout hatchery operated by the Tasmanian government, this strategy has become the main method of stocking small to medium sized trout fisheries. Previously, there has been limited assessment of this strategy, other than via angler catch details, mainly collected by a relict postal survey conducted since 1986. There has been no formal examination of growth or survival. A series of fishery assessments conducted at Penstock Lagoon between 2013 – 2018, has helped shed some light on this subject. The information collected suggests the strategy has merit, but fine tuning is needed to optimise returns to meet key fishery performance indicators.

Larval dispersal as a driver of population connectivity and genetic diversity in Victorian common galaxias *Galaxias maculatus*

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The dispersal of larvae and juveniles across a species' range is a crucial component to maintaining population connectivity in many marine and freshwater fish species. When effectively maintained, this connectivity helps promote the genetic health of all connected populations, buffering them from both present and future abiotic and biotic stresses. The common galaxias *Galaxias maculatus* is a short-lived amphidromous fish species with an extensive larval marine phase. The spatial extent of larval dispersal is unknown for Victorian populations of common galaxias however, in other countries (e.g. New Zealand) populations have been shown to exhibit high dispersal rates during larval phase. We sampled returning juveniles from multiple rivers across the common galaxias' range in Victoria. Our study uses highly resolving genomic techniques to characterise genetic diversity, population genetic structure and the spatial scale of juvenile dispersal among Victorian rivers. We investigate whether abundance estimates of juveniles returning to each river after their marine phase are correlated with levels of genetic diversity seen in each juvenile cohort. We provide new insights into relationships between abundance data and the genetic health of populations and the potential role of larval dispersal in maintaining genetic diversity in amphidromous fish species.

Intercontinental population genomics of a Gondwanan galaxiid

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Galaxias maculatus (common Galaxias, jollytail, inanga, Puye, Falkland's minnow) is the world's most naturally widespread freshwater fish with an intercontinental distribution that ranges from Western Australia eastwards as far as the Falkland Islands. The species is amphidromous with marine dispersed larvae and saline tolerant adults but readily establishes non-diadromous populations in isolated inland water bodies. Landlocked populations show characteristic changes in morphology including reductions in vertebral number and increased numbers of gill rakers and have often been described as separate species. We have examined the population genomics of this species using a genotyping by sequencing approach evaluating 3800 single nucleotide polymorphisms in landlocked and diadromous populations from Tasmania, mainland Australia, New Zealand and the Falkland Islands. The resulting data supports expectations of genomic divergence based on geographic separation and the duration of inland isolation. Further analysis of the SNP data will examine convergent genomic selection associated with the loss of diadromy in inland populations.

Seascape Effects on Temperate Reef Fish: Implications for Marine Conservation

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Understanding how organisms respond to habitat patterns within seascapes is fundamental for designing effective conservation strategies. There has been a recent increase in studies applying the conceptual framework of landscape ecology in the marine realm, reporting how the composition (e.g. type) and configuration (e.g. size, proximity) of habitats within coastal seascapes relate to the distribution of species and ecological processes. However, few studies have investigated how temperate reef fish respond to seascape patterning. This study employed a multi-scale approach to explore how habitat patterns explain the distribution of temperate reef fish within Jervis Bay Marine Park. Our results suggest the connectivity (distance) and size of reef and seagrass habitats is an important predictor for the distribution of temperate reef fish, with a more abundant and diverse fish assemblage found on reefs close to large seagrass beds. The influence of adjacent seagrass beds on temperate reef fish is likely due to many species using seagrass as nursery or foraging areas. These findings demonstrate the critical need for marine park design to consider the spatial arrangement of multiple habitat types to maximise conservation outcomes.

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Understand fish metapopulation persistence with network approaches

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Dispersal among populations is essential to ensuring the persistence of marine species, particularly those which are targeted in our fisheries. The dispersal potential, or connectivity, of most species is largely determined by the early life history characteristics and the geographic setting of populations. Here, we investigated metapopulation persistence using a network approach to analyse and visualise metapopulations dynamics. Traditional demographic approach for studying population dynamics has been implemented to explicitly include dispersal dynamics to account for losses and gains among subpopulations. We focused on two important fish species, the snapper (*Chrysophrys auratus*, formerly *Pagrus auratus*) and the King George whiting (*Sillaginodes punctatus*), found throughout the South-East Marine Region of Australia. These species represent contrasting life history traits, the snapper is characterised by a short pelagic larval duration phase, whereas the King George whiting larvae spend a much longer time in the larval stage. We used a biophysical larval dispersal model to simulate dispersal behaviour and develop metapopulation networks, where habitat patches with subpopulations are represented by nodes and dispersal connections are represented by linkages. We calculated and identified network metrics indicative of persistence to demonstrate the power of this approach in identifying key drivers of metapopulation persistence.

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Population genomics of coral trout (*Plectropomus*) in the Coral Sea and Great Barrier Reef

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Coral trout (genus *Plectropomus*) are a group of iconic predatory reef fishes and represent important commercial and recreational fisheries in Australia's tropics. The common coral trout, *P. leopardus*, are abundant through the Great Barrier Reef and occur on several remote atolls in the Australian Coral Sea Marine Park. Studying how these populations are connected is crucial for defining management units, implementing effective marine reserves and understanding the resilience of remote populations through time. This study used modern genomic techniques to test for patterns of population structure among *P. leopardus* on the Great Barrier Reef and the Coral Sea. Genetic structure was compared to regional oceanic currents to investigate the influence of environment on dispersal and connectivity. Patterns of selection were also compared between populations to test for signatures of localised adaptation.

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Stock structure of tropical clupeid populations

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Clupeiform fishes are a critical group in supporting higher trophic levels and commercial fisheries. Temperate clupeiformes have been intensely studied, however tropical species have been relatively ignored. The objective of this study was to use ecological and genetic approaches to elucidate the hierarchical population structure among a group of tropical clupeiformes on the Great Barrier Reef. The common tropical sprat *Spratelloides delicatulus* was sampled over multiple year. All life stages were most abundant within the lagoons of reefs when compared to inter-reefal waters; suggesting a strong degree of reef association in comparison with previous open water assumptions. Population genetics of *S. delicatulus* suggested separate stocks of this tropical clupeiform over spatial scales greater than 800km. Variation in size to maturity and patterns of growth correlated with genetic differentiation over broad spatial scales concurring with our conclusion of stock structure. Surprisingly, genetic substructure was found between reefs separated by 10s of kms in the Capricorn Bunker. We argue that reef fidelity, spawning behaviour and reef geomorphology play a role in maintaining higher levels of genetic diversity. Our results for tropical sprats contrast with patterns for temperate clupeid that generally have well mixed stocks over scales in excess of a 1000km.

Partnerships Underpin Sustainable and Responsible Recreational Fisheries

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Recreational fisheries that use rod and reel (i.e., angling) operate around the globe in diverse freshwater and marine habitats, targeting many different gamefish species and engaging hundreds of millions of participants. Whether anglers engage in catch-and-release or are harvest-oriented, there is potential for recreational fisheries to be conducted in a manner that is neither sustainable nor responsible. There are also many examples in which recreational fisheries are well-managed and anglers (and the angling industry) engage in responsible behaviours that contribute to long-term sustainability of fish populations and the sector. I will argue that partnerships (of various sorts) underpin sustainable and responsible fisheries.

Looking a little deeper: The importance of temperate mesophotic ecosystems to scientists, managers and recreational fishing

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To be provided

Do tropical reef fishes depend on seaweed meadow habitats?

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Habitat-based metrics are a key component of management plans seeking to sustain diverse and productive fish communities in our marine estates. To be adaptive, these management plans must understand how and why fishes respond to changes in habitat condition over space and time. We used a meta-analysis of 24 independent studies from around the world to explore whether seaweed meadows are important for fish diversity, abundance and replenishment in tropical seascapes. While we found relatively few tropical fish species that could be considered seaweed habitat specialists, seaweed meadows housed a large proportion (61-84% on average) of the local pool of fish species inhabiting seaweed, seagrass and coral reef habitats in each region. Patterns of relative abundance suggest at least 43 fish species may be particularly dependent on tropical seaweed habitat during their life history, including several important fishery target species. While many of these fishes occupied seaweed habitats throughout their life, around half of the species exhibited ontogenetic shifts to/from coral reef. Habitat percent cover was a significant predictor of abundance for many seaweed-associated fishes, indicating their population sizes and recruitment rates are vulnerable to the changes in seaweed habitat condition that arise from local threats and climatic forcing.

Unseasonal reductions in macroalgal canopy height have lasting effects on tropical fish communities

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Coastal marine habitats are vulnerable to disturbances (e.g., marine heatwave, cyclones) which may affect their capacity to support a diversity of reef fishes. High profile examples include the local extinction of fishes from coral reefs after key habitat components were lost following bleaching events. Observational studies of fish occupying tropical *Sargassum* meadows have indicated changes in macroalgal canopy structure are a key predictor of fish diversity. Here, we use a field experiment to tease apart the importance of canopy height for fish diversity by halving the height of macroalgal canopy in several *Sargassum* meadows within Ningaloo Marine Park. We then assessed short- (days), medium- (months) and long-term (years) responses of associated fish communities and their predators. Relative to reference sites, experimental meadows had significant reductions in fish species richness and abundance (~25% and ~80%, respectively) five-days post-disturbance. Although *Sargassum* canopy had recovered two years later, some species continued to be absent from experimental meadows. Our results demonstrate that macroalgal canopy height is a key driver of fish diversity in tropical settings, and that unseasonal

disturbances that cause habitat degradation can have lasting effects upon fish biodiversity. Therefore, monitoring of canopy height should provide a key indicator of seaweed meadow health.

Multi-scale habitat associations of serranid fishes across coral reef and macroalgal meadows at Ningaloo Reef, Western Australia

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Serranids play important ecological roles in marine ecosystems as predators and support valuable fishing and tourism industries. They are known to occupy a range of tropical marine habitats including coral reefs, macroalgal meadows, seagrass beds and mangrove forests. Yet within these broad habitat types, some species prefer microhabitat structures such as tabular corals. We examined whether habitat condition could be an indicator for the distribution and abundance of serranids at Ningaloo reef across both coral back reef and macroalgal meadows over a six-year period (2013-2018). All species found during surveys were within coral back reef habitat, while only 6/17 species were found within macroalgal meadows. The dominant species found during surveys was *Epinephelus rivulatus* (78% of total) which predominantly occupied macroalgal meadows; the most abundant coral-affiliated species was *E. fasciatus* (10% of total). Inter-annual comparisons revealed shifts in abundance and size structure of species across the Ningaloo lagoon, particularly *E. rivulatus* within macroalgal meadows. Concurrent surveys of habitat condition suggest differences in habitat microstructure may be a key predictor for serranid abundance patterns. Understanding multi-scale patterns of fish-habitat association is essential for sustainable resource management to assess and forecast the consequences of changing habitat conditions for these important fishes.

Do tropical reef fishes exhibit foraging microhabitat preferences in macroalgal meadows?

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Tropical macroalgal meadows are emerging as an important habitat for numerous fish populations and communities. Recent research has indicated that the abundance of macroalgal-associated fishes is correlated to different aspects of macroalgal canopy structure, such as canopy cover, height, and/or density. Our study aimed to explore a possible mechanism for these correlations, by exploring the foraging microhabitat preferences of 16 invertivorous fish species occupying macroalgal meadows at Ningaloo Reef, Western Australia. Instantaneous focal censuses of searching and feeding behaviour by these fishes was compared to microhabitat availability within each meadow using selectivity analysis. Despite sharing a similar trophic guild, we found these invertivorous fishes tended to diverge in their microhabitat use – some species preferred foraging within the canopy-forming macroalgae (*Sargassum*), while other species targeted abiotic substrata (sand, pavement, and/or rubble); most fishes avoided foraging within understory macroalgae (*Lobophora*, *Dictyopteris*). In revealing these microhabitat preferences among macroalgal-associated fishes, we find a behavioural mechanism that could explain why fishes respond to changes in different aspects of macroalgal canopy habitat structure over space and time.

The role of habitat composition in structuring the distribution of reef fish assemblages across a tropical to temperate gradient

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Ocean warming is driving rapid poleward expansion of tropical marine organisms, particularly in areas surrounding poleward flowing ocean currents. Each summer the East Australian Current transports fish larvae from tropical latitudes to temperate coastal and offshore locations. Increasing water temperatures are likely to reduce the physiological constraints for tropical fishes at higher latitudes, however little is known about the importance of habitat in the early establishment of such species. Here, we investigate the role of benthic composition and habitat characteristics in structuring reef fish assemblages across a tropical to temperate gradient, spanning 17 degrees of latitude along the east coast of Australia. Variation in fish assemblages among latitudinal locations was closely linked with benthic composition, especially for fishes of tropical affiliation, whereas habitat complexity only played a minor role. Results also suggest that generalist fish species are more likely to colonise temperate reefs, while species with highly specialised habitat requirements are less likely to successfully colonise high latitude environments. Our findings highlight the influence of local benthic composition in determining which tropical fish species may successfully establish populations in temperate environments in the future.

Degraded habitat increasing the susceptibility of resident fishes to disease

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Coral reefs represent one of the most diverse ecosystems globally but today are experiencing some of the greatest anthropogenic impacts. Overfishing, pollution and climate change are the three biggest threats to coral reefs, and is reflected by increasing coral mortality and proliferating macro-algae and bacterial species. We question whether this transition from healthy to dead coral habitat increases the susceptibility of resident fishes to disease. Fish gills exhibit unique bacterial communities that can act as a first line defence against diseases and pathogens, but it is unknown how this important community may be affected by habitat-borne pathogens. We investigated how the gill microbial communities of five tropical coral reef fishes responded to three habitat scenarios: a) healthy live coral (*Pocillopora damicornis*), b) dead algae-covered coral, and c) ambient seawater, to mimic pelagic conditions (control). Linking habitat degradation with the types and levels of pathogens found on the gills of several species of coral reef fishes will help define the health and state of resident fishes. Ultimately this information can provide more effective fisheries management and conservation of coral reef fishes by providing further protection to commercially important species (e.g. coral trout) and urge policy makers to mitigate anthropogenic threats.

Raising awareness of Australia's most threatened freshwater fish: the compilation of a Red Hot Redlist

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The number of Australian freshwater fish recognised as threatened has grown rapidly over the last decade. The ASFB threatened Fishes Committee (ASFB TFC) has coordinated a non-statutory national listing process since 1987. The current statutory listing process and legislation (the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)) commenced in 2000. The current ASFB TFC list contains 63 threatened freshwater fish, with 36 taxa recognised as threatened since 2000. By contrast, the EPBC list only contains 38 freshwater fish, 11 listed since 2000, including only 4 of the species listed by ASFB since 2000. Federal funding and conservation activities and actions under the recently introduced National Threatened Species Strategy (TSS) are effectively restricted to EPBC-listed taxa, with no freshwater fish listed as priority species under the TSS (only mammals, birds and plants). To raise awareness about the most imperiled fauna, the Threatened Species Hub in conjunction with the ASFB TFC held a workshop to identify the likelihood of extinction of 22 freshwater fish species considered at risk of extinction in the next 20 years. The results of the workshop are presented, along with the next steps in engaging the Commonwealth in progressing the listing of the identified species.

Statistical approaches to assessing threatened status in Australian freshwater fishes

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Quantitative understanding of extinction risk in freshwater fishes remains poor. Despite facing numerous threats, fewer than 40% of species have been assigned an IUCN threat level. However, ecological, life-history and biogeographical traits of species often correlate with extinction risk. These data may therefore be of use in predicting threat levels in taxonomic groups where detailed data on population and range size trends necessary for IUCN assessments are lacking.

Using information on ten representative traits, together with a composite phylogeny of over 300 brackish and freshwater species, we apply two statistical approaches (phylogenetic generalised least-squares regression and random forest modelling) to identify traits which contribute to the extinction risk of Australian freshwater fishes. These two approaches are complementary in their methods and assumptions, yet their conclusions are broadly consistent, and they display similar ability to correctly reclassify species already assigned a threatened status. Predictive models of extinction risk may therefore prove useful in identifying species needing formal (re)assessment and in informing future conservation strategies.

Although further trait data and model development are needed to refine our understanding of species' differing susceptibility to extinction, our results highlight the heterogeneity in threat type and severity across species of differing ecology and biogeography.

Monitoring a critically endangered galaxiid by portable pit tag detection

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The low cost and infinite lifetime of Passively Integrated Transponder (PIT) tags makes them a popular choice in fisheries management. Recent advances in PIT technology have meant smaller tags can now be used to mark smaller-bodied fishes, many of which are threatened. The suitability of 9 mm PIT tags for identification of threatened small bodied galaxiids was tested in an aquaria trial using Mountain Galaxias *Galaxias olidus* as a surrogate, with tags inserted into the abdominal cavity. Fish down to 73 mm LCF were tagged, and no significant difference in growth or survival was detected between control and tagged fish ($n_{\text{control}} = 34$, $n_{\text{tagged}} = 34$) after 90 days. Tag retention rate was high (96%), with only a single tag expelled. Following the aquaria trial, 38 critically endangered Stocky Galaxias *G. tantangara* were tagged to investigate individual movement in Tantangara Creek. Fish were monitored using a portable PIT antenna for six months between January and June 2018. Preliminary findings indicate *G. tantangara* exhibits a small home range (< 20 lineal metres) but can undergo larger up and downstream movements. PIT tag biomonitoring is likely a valuable tool in the management of other small bodied threatened fishes, especially other Australian galaxiids.

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Identifying and addressing water chemistry differences affecting post-release survival of Snake River Sockeye Salmon smolts

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The recovery plan for Snake River Sockeye Salmon includes annual releases of up to 1 million hatchery-reared smolts. A new purpose-built hatchery was constructed (near Springfield, Idaho) and began releasing smolts to Redfish Lake Creek (near Stanley, Idaho) in 2015. Various complications associated with fish transport contributed to reduced survival, but post-release success of Springfield Hatchery-reared smolts remained uncharacteristically low following optimization of fish transport protocols. Evaluation of smolts released in 2017 suggested that differences in water chemistry between the hatchery and release site may have contributed to morbidity and mortality observed after release. Follow-up experiments with pre-smolts confirmed that direct transition from hard, high-alkalinity water at Springfield Hatchery to soft, low-alkalinity water at Redfish Lake Creek caused a significant physiological stress response. Coping with a dramatic shift in water chemistry is difficult under any circumstances; coupled with the other challenges facing hatchery-reared smolts at release, it may be physiologically unmanageable. A variety of modified release strategies have been evaluated, including acclimation to water with an intermediate chemistry profile, water mixing at release, and in-transit water softening. Results of ongoing experimentation will be discussed, along with implications for future rearing and release strategies for Snake River Sockeye Salmon smolts.

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Assessing the benefits and risks of translocations in depauperate species: a case study of the conservation management of the critically endangered red-finned blue-eye, *Scaturiginichthys vermeilipinnis*.

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Translocations are increasingly implemented to assist conservation of declining native species and decrease their extinction risk. Establishing new populations via translocations helps spread the risk of sporadic events leading to extinction, thereby increasing the overall survival probability of the species. But initiating new populations comes with two main challenges: i) the genetic diversity of translocated populations will be reduced compared to the source, and ii) removal of founder individuals will decrease genetic diversity in source populations, placing them at greater extinction risk. We present an empirical study on the conservation of red-finned blue-eye, *Scaturiginichthys vermeilipinnis*. Several translocated populations have been established with founders sourced from this remnant population. Several generations after re-introduction, we show that translocated populations harbour reduced genetic diversity compared to the remnant population. This is due to i) failure of the founders to capture all the genetic diversity present in the source population, and ii) a failure to retain the genetic diversity of the founders through unbalanced breeding contributions. We argue, prior to undertaking translocations, the trade-off between extinction risk and retention of genetic diversity needs to be determined to establish the optimal conservation strategy to increase the long-term persistence and evolutionary potential of a species.

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Were the New Zealand and Australian graylings (*Prototroctes* spp.) distinct species?

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The Southern Hemisphere graylings (Prototroctidae) comprise two modern species; the extinct New Zealand grayling (*Prototroctes oxyrhynchus*) and the extant Australian Grayling (*P. maraena*). The New Zealand grayling was formerly described as one of the most common New Zealand freshwater fish, but has not been recorded since the 1920s. Approximately 20 preserved specimens are held in museums. The Australian grayling, native to south eastern Australian coastal catchments, has declined since European settlement, and is listed as vulnerable. The two species are morphologically very similar, and presumably had a similar biology, however the genetic relationship between the two species is unstudied. We sampled Australian Grayling from Tasmania and extinct grayling from New Zealand, encompassing the geographic distribution of the species. Using genetic techniques specific to formalin preserved specimens, we obtained partial mitochondrial cytochrome b sequence from the New Zealand grayling. Phylogenetic analysis indicates a strongly supported sister relationship between the Australian and New Zealand grayling. The level of divergence (~8%) supports separate species status and indicates a divergence time during the Pliocene around 4 million years ago, and the possibility of multiple colonisation events of New Zealand when fossil taxa are taken into consideration (e.g. 16-19 Mya Saint Bathans Grayling taxa).

Investigating the trophic ecology of a migratory benthic shark using stable isotope analysis

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Many shark species undertake large-scale migrations and can impact the ecosystems they frequent, however migration in benthic sharks is largely understudied. In this study, we applied stable isotope analysis to investigate spatial and temporal feeding habits of a migratory benthic shark, *Heterodontus portusjacksoni*. Port Jackson sharks were used as a model species as they migrate annually in large numbers and their impact on resource availability in coastal ecosystems could be substantial. Samples were collected from wild sharks throughout their four-month breeding season (July-October) and analysed for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$. Multiple tissue types (whole blood, plasma and fin tissue) were used to gain a snapshot of movement and feeding habits over different time scales. Isotopic ratio $\delta^{15}\text{N}$ of whole blood indicated that three NSW shark populations utilised similar food sources (Jervis Bay 12.89‰, Sydney 13.38‰ and Port Stephens 13.08‰), whilst the Melbourne population appeared to feed at a higher trophic level ($\delta^{15}\text{N}$ =14.96‰). There was also evidence of a potential diet shift during migration as both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ of Jervis Bay sharks increased over the breeding season when sharks were resident. These data indicate that benthic sharks may feed opportunistically to take advantage of locally abundant prey items.

Fine-scale site fidelity and social network structure of a reef manta ray population

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Reef manta rays (*Mobula alfredi*) occur in small, isolated populations associated with island or coastal reef systems, and are susceptible to anthropogenic impacts. *M. alfredi* are often observed interacting in groups, and perform many apparently socially-mediated behaviours. Social structure has been shown to affect spatial ecology in other elasmobranchs, and may be an important link between the behaviour of individuals and population-based phenomena such as disease transmission, response to environmental change and susceptibility to fisheries.

In this study we provide quantitative evidence for structured social relationships in reef manta rays (*Mobula alfredi*). We show that the reef manta ray population in Raja Ampat may be partly segregated into communities displaying strong and fine-scale preferences for particular locations, with social network structure that is conserved over time. By controlling for non-social factors, we show that reef manta rays exhibit social preferences that are not simply the result of common attraction to particular habitats or resources.

Results suggest that effective conservation and management of *M. alfredi* should consider how variation in individual social behaviour and habitat use shapes population structure, and may be used to guide plans for minimal-impact dive tourism in key habitats.

Stingray sociality – A case study for the utility of heterarchical analysis in understanding animal societies

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Sharks and rays aren't typically considered social creatures, but many have the brain capacity necessary to develop and maintain complex social repertoires. Smooth stingrays reportedly form large breeding aggregations and have the brain size and complexity necessary for social behaviour, yet no formal assessment of their sociality exists. In Jervis Bay, Australia, smooth stingrays have been provisioned food at a local boat ramp since 1985. We took advantage of their attraction to this site to conduct a heterarchical analysis (dominance hierarchy and social network analysis) based on their agonistic interactions. We observed a stable, relatively linear but shallow dominance hierarchy dominated by a single individual. Social network analysis revealed a non-random social network centred on the dominant individual. The observed social structure was thus reflective of a despotic society. Contrary to previous research, size did not predict dominance but it was correlated with network centrality. The factors determining dominance of lower ranks were difficult to discern. This study provides the first heterarchical assessment of stingray sociality, and supports our hypothesis that this species is capable of social organisation. Given higher dominance and centrality relate to greater access to the provisioned resource, the observed social structure likely has fitness implications.

Animal-borne video reveals novel habitat-use in white sharks

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Traditional forms of marine wildlife research are often limited to coarse telemetry positions or surface-based observations, restricting their use in determining fine-scale behaviours such as predator-prey events and interactions with habitat features. We use a newly developed suite of sensors, including animal-attached cameras, to reveal novel foraging behaviour by white sharks, *Carcharodon carcharias*, within areas of kelp forest in the Dyer Island Marine Reserve near Gansbaai, South Africa. All white sharks tagged in this study were found to spend time adjacent to kelp forest, with several moving through densely covered areas, navigating through channels and pushing directly through stipes and fronds. Cape fur seals, *Arctocephalus pusillus pusillus*, were only encountered within kelp forests and displayed predator evasion techniques. For the first time, we reveal the use of kelp forest habitat by white sharks, previously assumed inaccessible to these large predators.

The cryptic lives of tiger sharks – hidden complexities and enigmatic behaviours in a three-dimensional realm

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Tiger sharks (*Galeocerdo cuvier*) are a keystone predator in the food chains of many tropical reef systems worldwide. The development of new biologging technologies have increased our capacity to investigate the movement ecology of these animals. In May 2017, we deployed CATS camera and diary tags on 20 tiger sharks at Ningaloo Reef, Western Australia for durations of 7–48 hours. The tags were clamped to the dorsal fin and recorded both physical parameters such as depth and temperature, and *in situ* measurements of animal trajectory and locomotion, which enabled calculation of dive geometry, swimming energetics and path tortuosity. Concurrent videos enabled behavioural validation, habitat mapping and interactions with prey to be recorded. Movements of sharks varied among habitats, with the most striking differences found between inshore (depth <25 m) and offshore environments (25–96 m depth). The amount of time spent vertically moving, dive angle, and predicted energy expenditure all increased with habitat depth. Tiger sharks displayed a high affinity for sandflat environments, where several prey species were encountered and relative energy expenditure to capture prey was predicted to decrease. Generally, our results suggests that the movements and habitat occupancy of tiger sharks conform with strategies to optimise energy conservation.

Project AIRSHIP: Spotting sharks using blimp-mounted cameras for conservation and human safety

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Managing shark-human interactions is a key social and environmental challenge that needs resolving if we are to maintain shark populations and ecosystem function. Shallow coastal marine environments are known to provide nursery habitats for many shark and ray species. These shallow nearshore areas are also areas where recreational activities such as swimming and surfing are concentrated. We developed a novel active tracking approach using blimp-mounted cameras to continuously track the presence and movement of sharks, rays and other species. The blimp provides a means for assessing the shallow water space-use and beach visitation rates of large marine animals, providing continuous 8-hour coverage. A "spotting" trial was conducted to determine the reliability of this method in different weather conditions and depths. Mobile shark analogues were deployed daily at two depths. Footage was later shown to lifeguards to identify whether the shark analogue was present or absent from the clips shown. During the field trials, the movement behaviour of numerous sharks, rays, fish and seals was also recorded. This technique has relevance to scientists monitoring the movement animals in shallow nearshore environments. The project addresses the key management objective of preventing unwanted shark-human interactions; providing safer beaches whilst conserving marine life.

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Long-term , inter-regional variation and drivers of growth in an iconic fisheries species

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Long-term biological histories are key tools in forecasting responses to future ecological and environmental change. Accordingly, temporal trends of fish growth, which is a primary predictor of population productivity and fishery biomass, are important considerations in species management. We reconstructed a multidecadal (37 years) growth chronology and identified growth drivers of an iconic commercial fish species in Australia, snapper (*Chrysophrys auratus*). We focused on four key fishery areas in South Australia that are oceanographically and ecologically diverse. Otolith (ear stone) sclerochronology combined with a mixed-modelling approach was used to identify growth variation. Chronologies were developed at both annually and seasonally resolved scales. Environmental factors (sea surface temperature, chlorophyll-a and Southern Oscillation Index), biological performance indicators (recruitment) and anthropogenic influences (commercial catch) were assessed as individual and interactive drivers. We revealed significant temporal trends and inter-regional variation in snapper growth that was driven by intrinsic and extrinsic factors. This study highlights an effective and inexpensive method for exposing long-term biological trends and responses to changing environments. This will enable informed ecological predictions to mitigate risk and shape sustainable management of an important natural resource and industry.

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The quantification of large-scale, systematic changes in rocky reef fish assemblages across the NSW Marine Park network using Baited Remote Underwater Video

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Few analyses exist worldwide that have compared large-scale, representative networks of marine protected areas. This is despite the signatory countries to the UN Convention on Biological Diversity committing to implementing MPA networks by 2012. The New South Wales network of marine parks provides additional protections for ~33% of the state's coastline via multiple management zones – with Sanctuary Zones providing the highest levels of protection (no-take zones covering 6% of the coastline). Here, we report the temporal changes associated with rocky reef fish assemblages across the NSW network spanning much of the state's 2000km coastline. There were clear and consistent increases in the relative abundances of target species as a group and large fish over 30cm within the no-take zones compared to the fished zones within and outside of the marine parks. The main target species on rocky reefs *Chrysophrys auratus* (pink snapper) showed dramatic differences among the zones. Intriguingly, all marine parks showed clear patterns of more snapper in no-take areas, however, the sizes of the absolute effects were much larger in the north of the state than the south. Overall, this study provides a unique and timely assessment of a significant component of Australia's MPA network.

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Laying the foundations of South Australia's Blue Infrastructure Initiative: Windara Reef Stage 1

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Phase one of Windara Reef marks the first step to trialling methods to restore shellfish reef habitats that were historically prolific in South Australia's coastal waters. Developed under the broader scope of the Blue Infrastructure Initiative, the transition from concept development, stakeholder and community engagement through to reef construction has provided a foundation for shellfish restoration and supporting fisheries productivity in South Australia. Guided by a Habitat Enhancement Working Group made up of eleven stakeholder representatives across three levels of Government, commercial and recreational fisheries, non-profit organisations and community, Windara Reef is now the largest shellfish reef development in Australia. This project highlights the importance of co-management and community stewardship in raising both public and political awareness of the forgotten shellfish reef habitat, its ecosystem functions, traditional owners and fisheries enhancement. The first development phase in the construction of Windara Reef, led by State Government, demonstrates a 'hands on' approach to site management, policy, biosecurity and construction in partnership with The Nature Conservancy, University of Adelaide, the Yorke Peninsula Council and RecFish SA. This project highlights the importance of collaboration in delivering shellfish reef restoration projects and provides examples of site management considerations into the future.

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Large-scale synchrony in NZ fish growth and its implications for fishery productivity

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Fishing and climate change are impacting marine fish stocks but disentangling the relative importance of these factors has proven difficult due to a lack of long-term observational data. We generated novel long-term (50+ years) growth chronologies for four commercially important coastal and shelf NZ fishes (snapper, tarahiki, hoki and ling) using the information naturally recorded in otoliths. We found evidence for temporal synchrony among spatially segregated stocks of snapper and hoki, but not for tarahiki and ling. We successfully related inter-annual growth variation for each species to a range of climate (SST and Inter-decadal Pacific Oscillation Index) and fishing measures (spawning stock biomass), highlighting the importance of these external drivers on fisheries productivity.

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Taxonomy to support biodiversity conservation of Australian rainbowfishes

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A sound systematic framework is the vital first step into documenting and protecting biodiversity, especially in rapidly degrading aquatic environments that harbour high levels of cryptic species. Taxonomic programs to distinguish and describe species are essential for research, legislation and management. Without them confused identity, confounded ecological data, and unrealised extinction reign supreme. Rainbowfishes (family Melanotaeniidae) are brightly coloured small fishes common in fresh waters of the New Guinea-Australia region. They are a common and significant component of freshwater ecosystems, have cultural importance, and are popular in the aquarium trade. The number of described species in the group has increased rapidly in the last decade, largely attributable to the use of genetic techniques. All of the recently described species however, are from New Guinea. This study aims to improve biodiversity knowledge by undertaking taxonomic reviews of Australian rainbowfishes using museum material guided by the results of genetic data. Progress to date highlights that Australian rainbowfishes as a group are rich with narrow range endemics that are vulnerable to habitat modification and climate change. Showcasing the recently described Daintree Rainbowfish we review a modern combined lines of evidence approach to taxonomy that strives to inform stakeholders and conservation efforts.

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It's now or never....the future of threatened small-bodied freshwater fishes in the southern Murray-Darling Basin

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More than half of the freshwater fishes in the Murray-Darling Basin are small-bodied (growing less than 15cm long). These small-bodied freshwater fishes typically possess traits that make them vulnerable to environmental change, such as being short-lived, having limited dispersal abilities and occupying small home ranges. Not surprisingly, many have declined across the Basin, and some are at risk of extinction. The Lower Murray, a hotspot for 80% of the Basin's small-bodied freshwater fishes, provides a prime example as already threatened species were impacted by critical water shortages (2007 to 2010) during the millennium drought.

So how do we attempt to ensure the long-term future of these species?

Firstly, acknowledge that, whilst critical to the persistence of some species, previous recovery measures have not matched the scale of the problem. Next, accept that translocations of considerable numbers of fish over extended periods (i.e. more fish, more often) are a necessary prerequisite to create a network of self-sustaining populations to combat fragmentation and localised

impacts, which need to be supported with complimentary restoration (flows, habitat and alien species). Lastly, concede its now or never for some threatened small-bodied freshwater fishes (think Yarra Pygmy Perch). Simple right?

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Re-establishing Macquarie perch in the Ovens River: Actions, engagement and a novel evaluation approach

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The nationally endangered Macquarie perch was historically widespread across southeastern Australia, but is now restricted to several small and isolated populations, prone to environmental and genetic stochasticity. Macquarie perch was historically abundant in the Ovens River but underwent dramatic declines to the point where they were considered locally extinct. Since 2011, Macquarie perch have been released across a 50 km reach of the Ovens River with the aim of re-establishing a self-sustaining population. Released fish consisted of hatchery produced fingerlings and juvenile fish translocated from Lake Dartmouth. We present the outcomes of a program evaluation in 2018. Specifically, electrofishing surveys revealed Macquarie perch were distributed throughout the Ovens and Buffalo River, having dispersed well upstream of release sites. Using a novel and non-destructive monitoring approach, genetic samples from these fish were compared with samples taken from all translocated fish and broodstock (parents of all fingerlings) enabling an assessment of survival, growth and whether fish are reproducing. The program has been successful in re-establishing the foundations of a self-sustaining Macquarie perch population along with generating an engaged and supportive community, with the evaluation results providing important information to help guide future programs aimed at re-establishing threatened riverine fish populations.

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Spawning habitat of Macquarie perch in the Cotter River, Australian Capital Territory.

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Filling of the enlarged Cotter Reservoir commencing in mid-2013 saw a cessation in recruitment for the resident population of endangered Macquarie perch. Recruitment failure was attributed to the headwaters abutting natural instream barriers as it filled, preventing access to spawning habitat. A full reservoir 2016 resulted in inundation of barriers and successful recruitment, though characteristics and location of spawning habitat remain unknown in this catchment. This study aimed to determine the location and characterise the microhabitat features of Macquarie perch spawning habitat in the lower Cotter River upstream of Cotter Reservoir. Twelve riffles from three reaches in the lower Cotter River were sampled for Macquarie perch eggs fortnightly from October – November 2017. Eggs sampling and microhabitat characteristics of stratified quadrats were measured for each riffle. Macquarie perch eggs were detected from one reach (the reach immediately upstream of Cotter Reservoir) and on three of the four riffles within this reach. There was no detectable difference in microhabitat characteristics between riffles containing eggs and those that did not. Failure to detect Macquarie perch eggs in the upstream-most two reaches may be because of sampling intensity within riffle or spawning occurring in adjacent riffles that were not sampled.

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Fish are smarter than you think: Implications for welfare

Culum Brown¹

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With more than 30,000 species of fish on the planet, they represent more than half of the vertebrate diversity. Despite the fact that we interact with fish in a myriad of ways (fisheries, aquaculture, scientific research), they attract very little attention from a welfare perspective. Indeed, until recently the common view was that fish are automatons; primitive animals that lack cognitive sophistication. Over the last 30 years, however, that position has changed dramatically. There is now ample scientific evidence that fish are just as sophisticated as any terrestrial vertebrate and in many cognitive realms they out-perform them. Here I showcase fish intelligence with a view to demonstrating that they are sentient and capable of feeling pain.

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Fish welfare standards in aquaculture

Melina Tensen¹

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If we accept that fish are sentient, then we have an ethical obligation to treat fish humanely and avoid practices that have the potential to cause them pain, injury, suffering, fear or distress. In Australia, Animal Welfare or Prevention of Cruelty to Animals Acts cover vertebrate animals, but only some include fish, despite all fish being vertebrates. The acceptance of sentience in fish has significant implications for the treatment of fish in commercial fisheries, in recreational fishing and in fish farming. With the development of animal welfare standards for farmed Atlantic salmon, the RSPCA hopes to contribute to improving animal welfare in this latter sector where it is essential that those responsible for managing farmed fish ensure fish welfare is an integral part of every aspect of production every day.

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A remote-operated vehicle reveals the effects of capture on post-release behaviours of sharks

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Publish consent withheld

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The effectiveness of three common fish anaesthetics on the native estuarine fish, the Blue-spot Goby (*Pseudogobius* sp.)

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2. CAPIM, The University of Melbourne, Melbourne

The efficacy of three anaesthetics was investigated in adult Blue-spot gobies (*Pseudogobius* sp.). Induction, recovery, and 24- and 48-hour survival was determined for clove oil: 50 mg/L, 75 mg/L, 100 mg/L, tricaine and benzocaine: 200 mg/L. All of these were sufficient to induce complete anaesthesia within 15 minutes for all individuals. Post-anaesthesia, most individuals (94%) reached full recovery within 25 minutes. No mortality was observed at 48 hours regardless of anaesthetic used. As predicted, an increase in the concentration of clove oil resulted in a decreased time to complete anaesthesia, however, this did not affect recovery time.

The clove oil concentrations found effective for anaesthesia overlap with those reported for other Australian freshwater and estuarine fish species. These results demonstrate that the anaesthetics investigated are appropriate for sedation of a small, native fishes, with clove oil being the preferred choice, as it is the cheapest, safest for human handling and most environmentally friendly. Ultimately, the choice of anaesthetic is dependent on the sensitivity of the fish species, as well as the type of procedures to be completed. As part of fish research, it is critical to establish reliable anaesthesia methods that focus on the welfare of the study species.

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Influencing attitudes of recreational fishers to interactions with Sharks and Rays

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2. SARDI Aquatic Sciences, West Beach

The South Australian Government has undertaken an investigation into the treatment of marine life by recreational fishers, with a focus on reviewing the policy, research and management issues associated with recreational fishing for sharks and rays. Primary Industries and Regions South Australia (PIRSA) has developed and implemented an education and awareness campaign to firstly reduce fishing related mortality of sharks and rays through better understanding of appropriate gear and handling techniques and secondly, to enhance understanding of shark and ray biology by recreational fishers and the general community. This was achieved through the development of safe handling videos, media and website updates which have been provided to key stakeholders and promoted through PIRSA's FISHCARE program. PIRSA is also investigating a cross-jurisdictional approach to the issue through the development of a Fisheries Research and Development Corporation funded project to enhance the understanding of shark and ray biology by recreational fishers through the incorporation of citizen science data on appropriate gear types, handling and post-release survival. A key outcome of the project will be to elicit a cultural change in the sector of the importance of releasing sharks and rays to enhance survival rates and support ecosystem health.

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Ecosystem modelling to support freshwater fisheries management

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Ecosystem based fisheries management (EBFM) has gained considerable attention in marine systems over the last decade, including the use of ecosystem models to understand how changes in food-webs affect higher trophic levels. The use of quantitative ecosystem models to manage freshwater fisheries has lagged by comparison, despite well entrenched concepts linking seasonal flood pulses to primary and secondary production, with flow on effects for higher order consumers. This talk will contrast the application of ecosystem models in marine and freshwater environments, and demonstrate the application of ecosystem modelling to examine the impacts of flow management and food-web changes on fish production in the southern Murray-Darling Basin. This case study highlights a number of critical knowledge gaps but also provides valuable insights on the potential complementary roles that different management actions will likely have in restoring native fish abundances.

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A look under the hood of the National Carp Control Plan

Matt Barwick¹

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A multidisciplinary research program of unprecedented scope and complexity for fish biocontrol worldwide underpins the National Carp Control Plan, which aims to reduce carp impacts in Australia. In view of its high species-specificity and virulence, Cyprinid herpesvirus-3 (CyHV-3) is being investigated in particular as a key component of an integrated control plan.

Research now underway will deliver contemporary carp biomass estimates, examine the existing virome of carp in Australia, explore vectors for transmission, determine virus stability in carcasses and under varying salinity, complete testing of non-target species susceptibility, investigate possible water quality impacts and options for management, and epidemiological modelling. Integrated control will be critical to maximise likelihood of long-term benefits, informed by iterative modelling to enable consideration of optimal timing and sequencing of control methods, and ongoing monitoring.

In this presentation Research Project Manager Jen Marshall will provide a summary of the breadth and complexity of research now underway to inform decision making on carp control in Australia.

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The medium to long-term ecological effects of major carp reductions.

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The National Carp Control Plan (NCCP) is developing a plan for the potential release of the carp virus to control invasive common carp, *Cyprinus carpio*, in Australian freshwater environments. The NCCP commissioned a program of scientific, social, and economic research to develop the knowledge required to enable an informed decision of whether the virus release should proceed. Part of the scientific program involved an exploration of the medium to long-term ecological effects likely to result from major carp population reductions (i.e. over a 10 to >20-year timescale). To assess the likely ecological changes, we used both an expert elicitation process and an evaluation of the scientific evidence. In addition to predicting the ecological effects of carp reductions under various biomass scenarios (no control, 25%, 75%, and 100% reductions) the project includes an assessment of the confidence in predictions and a systematic review of scientific evidence for prioritised causal pathways. The outcomes of this project will inform management of likely positive and negative ecological outcomes of viral release under different scenarios and inform other NCCP projects that are evaluating costs and benefits and assessing community attitudes to carp biocontrol.

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Possible dissolved oxygen and nutrient impacts from mass carp mortality

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Carp herpes virus (CyHV-3) is arguably the most realistic biocontrol agent for the pest species *Cyprinus carpio* in Australia. However, risks and benefits of use must be carefully evaluated. Low dissolved oxygen and high oxygen concentrations are two potential risks from mass carp mortality. Impacts of carp decay were examined in bucket experiments, 720L ponds, 1000L mesocosms, and in a 2.5ha wetland. Oxygen depletion was strongly accelerated with increased temperature. Mesocosm experiments revealed that high phytoplankton productivity in response to nutrient enrichment can lead to supersaturated oxygen concentrations during the day, but the additional oxygen demand from decaying carp can lead to periods of anoxia. Six tonnes of dead carp were added to a 2.5ha wetland to simulate a mass mortality event. Biological oxygen demand increased to 80 mg/L and periods of anoxia were observed. Results from these trials are being incorporated into a coupled hydrological and biogeochemical model to predict oxygen and biogeochemical response to carp mortality in different aquatic habitats around Australia. Carp density, flow conditions, and temperature are determinant factors in how carp mortality associated with CyHV-3 will affect the River Murray, reservoirs, and wetlands. Key environmental and infrastructure assets may need protection against water quality challenges.

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How many carp are there in Australia?

Jarod Lyon, Ivor Stuart, Ben Fanson, Jerome Stocks, Leigh Thwaites, Andrew Norris, Matt Beitzel, Qifeng Ye, Shane Brooks

Effective carp control requires a fundamental understanding of carp abundance and biomass (total weight of carp in a given area) within representative habitats (i.e. rivers, lakes, billabongs, estuaries) and at appropriate geographic scales (local, river reach, river-basin, inter-basin). A collaborative project being undertaken by research agencies from across eastern Australia under the NCCP aims provide a robust estimate of carp abundance and biomass in a broad range of aquatic habitats, reaches and river basins across the country. We utilised historical catch data (carp relative abundance) supplemented with contemporary data collection in key sites to inform our biomass model. To convert relative abundance to total abundance, we undertook a range of capture-mark-recapture detection experiments in different habitat types across the eastern seaboard. Preliminary detection rates varied from 4% in large, lowland rivers, to 20% in small wetland habitats. Biomass estimates for different habitat types, and a combined total biomass/number of carp for Australia, will be presented.

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Four common misconceptions about a potential carp biocontrol virus, and implications for a control program

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There are four common misconceptions about the biology and use of cyprinid herpesvirus 3 (CyHV-3), a potential biocontrol agent for the common carp (*Cyprinus carpio*) in Australia. These will be discussed in the light of our earlier results, or planned studies.

Misconception # 1 is that CyHV-3 can infect, but not affect, a range of species in addition to carp. We have shown that the virus replicates in, and therefore infects, common carp only. # 2 suggests that genetic changes in the virus genome following release could possibly increase its host range. Lessons from evolutionary studies on herpesviruses, and from field observations with two different rabbit biocontrol viruses suggest otherwise. Misconception # 3 is that CyHV-3, alone, will be sufficient to control carp in Australia. Again, lessons from viral biocontrol of rabbits in Australia teach us that multiple broad-scale control measures will be required. Therefore, we have long-promoted the use of a genetic strategy to complement the effect of the virus. Finally, # 4 suggests that CyHV-3 can latently infect carp that survive infection. Although highly likely, this has not yet been proven. Differences between a persistent and a latent infection may be important in understanding the epidemiology of CyHV-3.

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Can the carp herpesvirus deliver safe and effective restoration of rivers and wetlands?

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Australia has a long history of success with biocontrol, but some notorious failures. We review the benefits, effectiveness and risks of cyprinid-herpesvirus-3 to target common carp (*Cyprinus carpio*). Success could boost native fish biomass to more than double the current level, but there is little evidence demonstrating that release can deliver effective, let alone safe, biocontrol of carp in Australian waterways. The virus may already be present in Australia. Overseas it has caused intermittent, localized mass-mortalities in aquaculture ponds and lakes, typically leading to short-term water quality problems and then recovery of carp populations. Experiments on Australian biota have reported unexplained high mortality rates of recreationally important and threatened fishes. As matters of national and international environmental significance under the *Environment, Protection and Biodiversity Conservation Act 1999*, we strongly encourage the Australian government to re-evaluate the susceptibility of all threatened native species and field-test the effects on free-living common carp in wetlands, rivers or mesocosms, including food webs connected to fish and waterbirds. Despite political pressures, there is no environmental justification to rush this viral biocontrol release. Before large-scale releases, contained field trials and independent species-specificity testing are essential, coupled with transparent peer-reviewed reporting. Australia cannot afford another disastrous biocontrol.

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Assessing the size structured pelagic ecosystems in the western Tasman Sea: A stable isotope analysis

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Ocean fisheries are increasingly managed by satellite imagery of sea level and sea surface temperature, but the ecosystem basis to these oceanic habitats is unknown. Mesoscale eddies are common features off Australia's East coast, providing distinct oceanographic habitats, with the direction of their rotation having powerful biological implications. This research will link size-based ecosystems of the western Tasman Sea, with trophic level estimates based on nitrogen stable isotopes composition of the major functional groups, to determine the trophic ecology of each oceanic environment. Trophic ecology and function can be revealed by quantifying a set of numerical food web parameters established from the relationship between body size and trophic level, such as: food chain length, trophic efficiency, and predator-prey mass ratios. The results displayed elevated trophic levels and lower abundance in the anti-cyclonic eddy environment compared with the cyclonic eddy across the entire size-structured study community from mesozooplankton to midwater fish. Anticyclonic eddy environments also returned higher predator-prey mass ratios and decreased trophic efficiency. These ecosystem metrics further our understanding of the effect of coastal ocean warming off eastern Australia, while information on the biomass, productivity, and resilience of each ecosystem, will be used to improve fisheries management.

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Deep-reef fisheries ecology in the Indo-Pacific

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Fishers across the Indo-Pacific target deep-reef species, but there is insufficient information for fisheries management in marine environments deeper than 50 m. We hypothesized that population structure and community assemblage of fishes would vary with depth and habitat type over a depth range of 50-260 m on the Great Barrier Reef. Further, we used fish otoliths (ear-bones) to identify regional stock structure at spatial scales of 10s-1000s of kilometres from Indonesia to Tonga. We found that depth, topography and hardness of substrate were good predictors of species distribution. Mesophotic fishes had varying degrees of habitat specialization. Closely-related species (of the same genus) had different habitat preferences and specialization, likely due to niche differences (*i.e.* diet, depth range). Otolith chemistry for three commercially-valuable eteline snappers showed regional spatial patterns. There were strong inter-species differences in otolith composition, indicating potential variation in growth, diet and habitat use. Some locations showed elemental signature differences between neighbouring Pacific island nations, suggesting separate stocks, but these varied among species. Spatial delineations among stocks can be enhanced with otolith elemental chemistry. This study demonstrated deep-reef fish communities vary by habitat type, but exhibit inherent vulnerability in the narrow depth ranges over which many species are found.

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Misidentification of Pacific Ocean billfishes by fisheries observers raises uncertainty over stock status

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Data collected by fisheries observers are important for effective fisheries management. With large, multi-species fisheries often catching a diverse range of species, the accurate identification of morphologically similar species represents an ongoing challenge. High levels of misidentification and misreporting of catch at the species level has been previously identified to influence the information that is used to determine the status of billfish. In this study, we investigated whether commercially landed black marlin were being misidentified by fisheries observers operating throughout the Pacific Ocean. Observed records of landed catch were compared to samples from those fish by genotyping across a suite of microsatellite markers. Genetic assignment testing revealed that, of 83 samples reported by observers as black marlin, 77.1% were genetically identified to be blue marlin and 2.4% to be striped marlin. The high rate of misidentification by observers places considerable uncertainty over historic catch ratios of Indo-Pacific marlin and stock assessments relying on the validity of these data.

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Accounting for ENSO driven fluctuations in a small-scale prawn trawl fishery

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Determining the impacts of non-fishing effects on stock abundance is an ongoing challenge within fisheries stock assessment and has implications for fishery management. Such effects can include large scale oceanographic processes such as the El Niño-Southern Oscillation (ENSO) which have been shown to influence trends in recruitment in a range of species. In South Australia, large fluctuations in the catch of *Penaeus (Melicertus) latisulcatus* from the West Coast Prawn Fishery (WCPF) have been observed, particularly following El Niño events. The challenge has been in differentiating between environmentally and fishery-driven changes in biomass or distribution patterns. Recently, a draft harvest strategy has been developed for the WCPF with performance indicators and reference points developed that for the first time take into account El Niño events. The key

Functional diversity and vulnerability of Australian freshwater fishes

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Biodiversity assessments have mainly focused on species richness but little is known about the diversity of species roles, i.e. functional diversity, while this is a key component to understanding the consequence of human impacts on ecosystems. We report Australian wide patterns of functional diversity among freshwater fishes at both the major drainages and individual river basin scale using four functional metrics (functional richness, evenness, divergence and specialization). Fish functional groups were defined using a combination of morphological and life-history traits. The aim of this study is to assess the contribution of taxa to each of regional drainage's functional diversity by measuring the functional uniqueness of each taxon within the drainage. The Timor Sea and the Northeast Coast drainages hosts more than 90% of the country's functional diversity. Interestingly, the North Western plateau drainage presented higher functional specialization despite having the lower species richness, which may be explained by functional uniqueness of fishes adapted to living in harsh arid conditions. Finally, we quantified the functional vulnerability to species loss as the proportion of unique functional groups supported by species listed as threatened by the IUCN Red List or, if species were not assessed by the IUCN, other measures of extinction risk.

Stages of embryonic development from zygote to hatching in the viviparous fish, *Gambusia holbrooki*

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Developmental staging is indispensable to study developmental pathways, genetics and evolution among taxa. Life-history stages have been previously described for few Poeciliid, however, proposed classifications are not generally applicable due to divergent morphology among different Poeciliid species. In Poeciliid, with placental developmental strategy, embryos receive the maternal investment throughout gestation. Therefore, normal morpho-physiological characteristics are often compromised by applying previously employed *in vitro* culture and embryo fixation approaches. Here, we describe the early development of the embryonic process in a livebearing fish, *Gambusia holbrooki*, based on detailed morphological diagnostics and overlay cardiac rate in embryos (post heart development) under normal conditions. Light microscopy observations of live embryos obtained from gravid wild captured females, allowed assignment of the development process into seven periods: zygote, cleavage, blastula, gastrula, segmentation, pharyngula, and hatching. Thirty-seven stages were determined and assigned within each of these periods applying a numbered staging system. At least one morphologic landmark for each of the embryonic stages was defined to maximize the accuracy of staging. The heart rates showed significant differences between stages. The novelty of the present study is the real-time, *in vivo* quantification of the heart rhythm variations and its application as a physiological marker for embryonic staging.

A new tree for an old problem: Resolving wrasses relationships - phylogeny and biogeography of *Coris* and Old World *Halichoeres* lineages (Family Labridae)

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The Labridae (wrasses and parrotfishes) is the seventh largest family of ray-finned fishes, contains ~630 species in 88 genera. Consistently in the top five families for species richness and local abundances on coral reefs around the world, they have been the focus of much ecological, evolutionary and biogeographic research. Although incompletely sampled in phylogenetic reconstructions, progress over the last 15 years has led to phylogenies representing all major lineages, 84% of genera, and ~50% of species. Several genera remain non-monophyletic in these phylogenies, but few attempts have been made to resolve this conflict with taxonomy. Here, we examine new and previously published sequence data (Rag2, S7, 12S, 16S) for two of the largest non-monophyletic genera: *Halichoeres* and *Coris*. We explore this new phylogeny and propose new generic delineations

What gurnard is that? revisiting Indonesian and Australian *Lepidotrigla*

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In 1984, Thomas Gloerfelt-Tarp and Patricia Kailola published a guide to “Trawled Fishes of Southern Indonesia and Northwestern Australia”, which provided a great insight to the diversity of shelf and upper slope species occurring in the area. Subsequent studies have revealed that the authors did not always correctly identify the species treated. An ongoing study of Indo-West Pacific species of the genus *Lepidotrigla* – by far the most speciose genus of the family Triglidae – has determined that none of the six species given available names was correctly identified, although the four regarded as not having names were at that time indeed likely to have been undescribed. A review of the ten species, their distributions and their relationships to others in the genus is discussed.

Using biochemistry to monitor the Murray Crayfish *Euastacus armatus* (Parastacidae)

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Haemolymph samples were collected from wild and captive held adult male and female Murray Crayfish *Euastacus armatus*. Haematological analyses were performed in order to determine reference values for this species including protein, albumin, globulin, creatine kinase, aspartate transaminase, glutamate dehydrogenase, glucose, gamma-glutamyltransferase, potassium, sodium, calcium, phosphate, chloride, uric acid, cholesterol, amylase and bile acids. Additionally, protocols for measurements of phenoloxidase and prophenoloxidase (part of the non-specific immune system in crayfish which leads to the melanisation and sclerotisation in stressed animals) are being trialled. Alterations from these reference values can be used to determine stress and disease state of the crayfish. These tests are being used to monitor the health and stress levels of Murray Crayfish intended for use in a large-scale translocation of crayfish from healthy populations to areas of the Murray River that no longer support crayfish. Murray crayfish populations in affected parts of the river dropped by 81% in 2010–11 due to hypoxic water events.

Fish tales and life as an ecological detective

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One of the privileges of working as a marine biologist in Australia is the great diversity of fishes and the extraordinary array of habitats in which they are found. My passion is the ecology of reef associated fishes and over three decades I have worked on them as, in my view, an ‘ecological detective’. This talk is about that detective work, the collaborators I have had and, in particular a talented group of research students where a combination of long-term data sets and new approaches has revealed a great deal. The tales of fishes are as follows: a damselfish on the Great Barrier Reef that is short lived and whose connectivity appears to be driven by catastrophic events such as cyclones; a long-lived fish found in temperate NSW that appears resilient to environmental perturbations, but has an inherent vulnerability – it only does well in urchin grazed barrens; and a tropical snapper that has stochastic recruitment, and ‘interviewing the recruits’ combined with biophysical modelling has been revealing. A great surprise has been how fish larvae have manoeuvred in our minds from drifting objects to small particles with mobility and surprising powers of orientation, this in turn is changing our understanding of population connectivity. Finally, on reflection, the changing face of fish biology, where we are all fortunate that the combined talents of males and females is making a difference to resolving the Grand challenges.

Integrating habitat suitability and population projection modelling to better inform the management of invasive common carp

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Common carp are a serious invasive species in south-eastern Australian waterways and cyprinid herpesvirus 3 (CyHV-3) has been proposed as a control measure. The release strategy and potential success of the virus will greatly depend on the population dynamics of carp. Carp survival and distribution are dependent on highly variable abiotic environmental factors, which vary over space and time. Consequently, sound population projection models are required to inform management decisions.

Here, we combine expert opinion and environmental datasets via Bayesian belief networks (BBN) to determine spatio-temporal habitat suitability for survival and recruitment. We then integrate these data into a carp metapopulation model. Importantly, we modelled carp recruitment and survival as continuous-time processes within the year. This novel departure from existing carp population models (which typically adopt an annual time-step approach) allows us to better align the model with a realistic time-scale for the virus (i.e. days to weeks).

To assess the accuracy of our demographic model predictions, we are testing the model against biomass survey data. Preliminary findings suggest that integrating habitat suitability data into demographic models can provide an adequate representation of carp distributions over space and time, enabling a strong basis for evaluating the effects of releasing CyHV-3.

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Integrated epidemiological and ecological modelling to inform policy – a case study to assist the decision of whether to release Cyprinid herpesvirus 3 (CyHV-3) to control invasive common carp (*Cyprinus carpio*) in southeast Australia.

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Common carp are a serious invasive species of the waterways of south-eastern Australia, and as a potential control measure, Cyprinid herpesvirus 3 (CyHV-3), has undergone extensive testing to confirm that it will not affect non-target species. However, any decision to release the virus is a complex one, requiring consideration of many social, ecological and economic factors, which are being co-ordinated by the National Carp Control Plan (NCCP).

In making the assessment of virus release, it is useful to be able to predict where and when it will have greatest impact on carp populations. To this end we are using a modelling approach which integrates hydrological, habitat suitability, demographical and epidemiological datasets. Preliminary results indicate that release of the virus will have maximum knockdown on high density populations in the spring and summer when aggregation is occurring.

This conclusion however is largely based on the assumption within the model that virus transmission occurs only via direct physical contact between carp, and not via water. This critical assumption will shortly be tested experimentally by an NCCP supported research project, and exemplifies how modelling, policy and experimental studies are being co-ordinated.

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Can dogs smell fish: using scent detection dogs to sniff out carp

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Scent-detection dogs have proven ability in terrestrial biosecurity and conservation, but limited evaluation to detect aquatic targets. Invasive fish are extremely difficult and costly to eradicate, so early detection methods are crucial. Current methods are resource-intensive and inadequate at low abundances. This study evaluated dogs' ability to detect an aquatic pest, common carp (*Cyprinus carpio*). Other invasive species were used to test dogs' discrimination: bullhead catfish and goldfish. Water samples were taken with carp present (positive), and aquaria containing no fish, catfish, or goldfish, respectively (negative samples). Samples were placed inside an automated apparatus and dogs evaluated samples using a go/no-go procedure. Completion criteria for dogs included achieving $\geq 80\%$ accuracy across all samples for four sessions. All dogs detected carp successfully, with an average sensitivity of 97.5% and specificity of 92.3%. Samples were then diluted and three dogs detected carp at dilutions equivalent to biomass of 37.4 kg/ha (a density of biological significance in terms of environmental damage). Dogs also successfully discriminated between carp and the other fish species. This research demonstrates that dogs can detect fish in water samples. This novel system has potential as an effective and economically-viable alternative for the detection of invasive aquatic species.

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The management of European carp in Tasmania

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Previously deemed absent from Tasmania, European carp (*Cyprinus carpio*) were first discovered in Lakes Crescent and Sorell in January 1995. As a result, the Carp Management Program (CMP) was established to contain, control, and ultimately eradicate carp from the lakes. Through the development of various techniques over 12 years (1995-2007), a complete eradication of carp from Lake Crescent was achieved using an integrated approach. By using these strategies in Lake Sorell, the carp population was estimated to have been reduced to less than 50 fish by 2009. However, a spawning event which occurred in spring that year resulted in the introduction of approximately 50 000 carp. Since then the CMP has used a combination of techniques which include intensive netting, biotelemetry, electro-fishing, barriers, and traps to target these fish as they become mobile. It is estimated that there are now less than 50 fish remaining, with over 99% of the original population removed. The CMP is at a critical stage which could see the complete eradication of carp from Tasmania over the next few years, providing spawning is prevented, and favourable environmental conditions occur in Spring.

Shark depredation in fisheries: How data from an Australian recreational fishery fits into the global picture

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Shark depredation, where sharks consume hooked fish, occurs in commercial and recreational fisheries around the world, causing extra mortality of target species, injury to sharks, and economic impacts for fishers. To quantify the rate of shark depredation and understand factors influencing its occurrence in a key recreational fishery in the Ningaloo Marine Park and Exmouth Gulf, Western Australia, we collected data through a boat ramp survey program. The mean shark depredation rate was 13.65% in this fishery, and depredation was higher in areas where fishing pressure was greatest. Using a novel application of underwater video cameras, we identified four shark species responsible for depredation and recorded a wide range of behaviour around fishing gear. To understand how this data fits in with the global occurrence of shark depredation, we present the results from an extensive review of this topic, which identified 48 literature sources from 1955-2018. These studies reported shark depredation in commercial fisheries around the world, with rates of depredation between 0.9% and 26%. This combined research on shark depredation provides important insights into this fisheries management and conservation challenge, at both the global and Australian level, and will inform future efforts to design strategies for reducing its impacts.

A conceptual model of banana prawn life history that informs both ecosystem services for fishery production while enabling water harvest for multiple use

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Fishery independent surveys of the commercial prawn community of the Gulf of Carpentaria have been undertaken annually for 15 years and generated indices of abundance for seven species.

The index of abundance for banana prawns is tightly correlated to annual banana prawn catch in the Gulf of Carpentaria. In addition, un-regulated annual flood flows from adjacent catchments are positively correlated with both the abundance index and the commercial catch. A new conceptual model of the banana prawn life history facilitates our understanding that, under diverse flow regimes, estuarine production, food availability, prawn growth, prawn predation and emigration vary markedly and moderate the annual fishery yield. The new model allows fishery managers to better understand the variation in 15-year indices not explained by flow, predict the impacts of anthropogenic flow modification, respond to likely landscape management change, and target new research to explore solutions to flow modification and barrier construction that benefit the NPF compared to a laissez-faire situation.

The last 25 years of research in the Gulf of Carpentaria enables researchers to inform water management policy; aiming to sustain the ecosystem services in estuarine and nearshore habitats for downstream fisheries, while enabling the harvest of water for extractive use.

The implications of varying environmental conditions on the development of a harvest strategy for the nt mud crab fishery

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The commercial sector accounts for approximately 88% of the mud crab fishery harvest in the Northern Territory (NT). Important commercial fishing grounds exist in the Gulf of Carpentaria (GOC), and due to restricted access during the wet season the majority of effort in the GOC occurs between March and December. From 2014 – 2016 the GOC received below average rainfall and unfavourable environmental conditions for the successful recruitment of mud crabs. Stock assessment model outputs indicated that mud crab biomass in the GOC had dropped, but it could not separate whether the decline was a result of environmental conditions or fishing pressure. In 2016/17, the GOC received average rainfall or higher, the catches and catch rates of mud crabs increased, and high numbers of large mud crabs were observed in the commercial catch. It is yet to be

determined if environmental conditions or fishing pressure had the greatest impact on mud crab stocks in the GOC, however the sudden influx of large crabs were not considered a result of recent spawning events. This suggested that during the period of unfavourable environmental conditions, the catchability of mud crabs was also a significant factor impacting the observed decline in biomass in 2016.

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Living in polluted waters: metabolic costs of exposure to nitrate and low pH of a native fish species

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In freshwater systems, the threat from a myriad of environmental stressors is prominent, including stress from nutrient effluents (i.e. nitrates) and altered pH regimes. Environmental stressors can disrupt organismal energy homeostasis and physiological performance via reductions in aerobic scope (i.e. maximal – routine oxygen uptake). Independently, nitrate and low pH affect energy allocation by increasing maintenance costs and disrupting oxygen uptake. The interaction between these two stressors may result in synergistic reductions in aerobic scope and subsequently reduce whole animal performance (e.g. swimming performance and growth rates). We explored the interactive effects of elevated nitrate and low pH on the energetic costs on the freshwater fish, spangled perch *Leiopotherapon unicolor*. Fish were exposed to a factorial combination of two pH levels (pH 4.0 and 7.0) and three nitrate concentrations (0, 50 and 100 mg/L). It was predicted that combined exposure to low pH and elevated nitrate concentrations would result in synergistic decreases in aerobic scope and performance. We show how aerobic scope, blood –oxygen carrying capacity and whole animal performance are affected by the interaction between nitrate and low pH and provide an insight into the possible mechanisms allowing fish to persist in degraded environments.

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Does harvesting of drift algae to reduce nitrogen in coastal marine ecosystems pose a risk to associated fish species?

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Pollution in coastal marine ecosystems continues to be a major anthropogenic stressor, largely due to the eutrophication it entails. As a direct consequence, drift algae mats comprise a nitrogen reservoir and its harvesting would provide a means of offsetting those inputs. Knowing whether they may function as an important ephemeral habitat and for what types of species is thus important for determining if its harvesting will result in beneficial or deleterious environmental outcomes.

The aim of our study was therefore to evaluate what animals are associated with drift algae and whether community composition changes depending on season, location and algal species. We sampled 3 different depths at 3 sites relatively close to the major nutrient sources in Port Phillip Bay (VIC) at four times over the course of one year. The distribution and abundance of drift algae varied considerably seasonally and spatially but were typically most abundant in spring and autumn. Although the fish assemblages varied largely due changes in algal biomass and species composition, they were comprised largely of cosmopolitan species that are locally abundant. These findings support the idea that the harvesting is likely to have a net benefit by providing another pathway for the removal of nitrogen.

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The use of Diffusive Gradient Thin-film units (DGTs) in contaminants concentration assessment and exposure risk for aquatic biota

Aldo Turco, Kirsten Broadgate, Nicholas Thyer, Elena Lazzarotto

The characterization and quantification of exposure to chemical pollutants is essential to understand and predict the possible effects on aquatic organisms' biology and physiology. Here we investigated a novel approach to estimate the concentration of labile metal contaminants in saltwater over a set time-frame. Diffusive Gradient Thin-film (DGT) sampling units have been used to quantify metals concentration from a groundwater source in a tidal inlet of South Australia. DGTs ability to capture pollutants concentration relies on a resin with a constant absorption rate for specific chemicals. DGT units were deployed at three depths (surface, mid-water and bottom) across 23 locations. Deployment occurred for a period of two to seven days which allowed us to test for saturation of the resin and bio-fouling formation on the units. Each deployment was matched with surface water samples for comparison. No differences were found between dissolved metal concentrations in water samples and labile metals in DGTs. Nonetheless, no bio-fouling was observed, and saturation did not occur for up to five days. Ultimately the results suggested that DGTs provide reliable data on time weighted average of labile metals and represent an innovative and useful tool to quantify exposure of fish and other aquatic organisms.

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Smooth toadfish (*Tetractenos glaber*) as an indicator of pollution stress in Western Port and other coastal embayments in Victoria, Australia.

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Western Port, in south eastern Victoria, is a large, semi-enclosed bay with significant ecological and social values. However the landscape has been altered substantially by anthropogenic activities in the last century and is under increasing pressure from rapid urban growth.

A report consolidating knowledge of the Western Port environment identified threats to environmental assets and critical knowledge gaps, which included the need to understand threats from toxicants. To address this, CAPIM sampled smooth toadfish (*Tetractenos glaber*) from areas within Western Port, Port Phillip, Andersons Inlet and Shallow Inlet over a two year period. Sites were selected to include some with known pollution inputs (impact) and others without (reference). To determine fish health, general condition indices, morphological and biochemical measurements and histological evaluations were done. Additionally, genome scans of single nucleotide polymorphisms (SNPs) using next generation sequencing were used to determine patterns of connectivity, levels of genetic diversity and tests for signatures of adaptive variation within toadfish populations.

Site specific differences were observed for several indicators and will be discussed in relation to measured water and sediment toxicant concentrations, and implications for the protection and improvement of the Western Port environment.

Freshwater Fisheries Management in Victoria – the last decade

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Over the last decade, successive Victorian State Governments have embraced recreational fishing like no other State or Territory in Australia. Over the last 4 years, this has culminated in a record \$46 million-dollar investment through the Target One Million program that, aims to get more people fishing, more often. As the Inland Fisheries Manager within the Victorian Fisheries Authority, I provide an insiders-view of our key achievements, how we empowered recreational fishers and, re-built our authorising environment.

I highlight some of our key fishery management outcomes; Introduced slot limits for Murray cod; recovered trout cod fishery in the Ovens river; established new stocked estuary perch fisheries; Angler Riparian Partnerships Program, Wild trout Fishery Management Program; Lake Eildon Murray cod development; Native Fish Report card program; and the development of a new GoFishVic App.

The common success factors to achieve these outcomes include:

- A management driven approach to commissioning applied science,
- Simplifying science results into real world language,
- Building knowledge and capacity of key stakeholder groups,
- Humanising the bureaucracy,
- Nourishing our sponsors and,
- Finding partnerships through common ground.

These fishery management experiences and lessons are equally valid for fishery researchers who can become more relevant by; lifting their horizon, working more closely with stakeholders, securing their funding base, having their research findings more adopted and understood, by a community thirsty for knowledge.

Monitoring fish response to environmental flows in a northern Victorian river

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Environmental flows are increasingly being used to restore native fish populations in flow degraded rivers. Providing environmental water is a significant investment, therefore it is critical to evaluate its effectiveness in achieving the intended outcomes for native fish. The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was established by the Victorian Government to monitor and assess ecosystem responses to environmental watering in priority rivers across Victoria. VEFMAP includes a strong focus on monitoring key processes that govern fish populations. Here we present preliminary results from an assessment of native fish dispersal (movement) in response to environmental flow delivery in a Northern Victorian River system.

We used two methods to assess fish movement responses to flow throughout the Loddon River and Pyramid Creek. First, we explore the movement of golden perch using acoustic telemetry to assess the role of flows and other factors in governing dispersal. Secondly, we assess how the entire fish community respond to specific environmental watering events by monitoring

fishways before, during and after the delivery of environmental freshes. The management implications of this work include the potential use of environmental flows to enhance colonisation of native fish species throughout the Murray Darling Basin.

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Spatial complexity in abundance, size, age and sex in populations of Southern Garfish in South Australia

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For Southern Garfish (*Hyporhamphus melanochir*), one of the most significant inshore fishery species of South Australia, the current levels of stock status are poor. Nevertheless, the stock assessments are based on spatially-limited, fishery dependent data, which may not be indicative of the status of the broad geographic stock. A recent FRDC-funded project (2015/018) has considered population characteristics of Southern Garfish throughout heavily and lightly fished areas of Gulf St. Vincent, using fishery independent sampling. The night-time sampling operations involved: visual counts of juveniles and adults that provided estimates of relative abundance; and dab netting that collected specimens to inform on size, age and sex. Between 2016 and 2018, thirteen localities were sampled twice (spring/summer and autumn/winter) at three depth zones (0-5 m, 5-10 m, 10-15 m). The results demonstrated unexpectedly high spatial complexity in the dispersion of fish with respect to size, age and sex that resulted in spatial differences in abundance, biomass, size structures and sex ratios at several spatial scales. At the regional scale, these data suggest three populations located in the eastern, northern and western parts of the gulf that experienced different demographic processes. The implications for stock assessments are considered.

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Establishing best practice classification of shark behaviour from bio-logging data

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Understanding the behaviours of free-ranging animals over biologically meaningful time scales (e.g. diel, tidal, lunar, seasons) gives important insights into their ecology. Bio-logging tools allow the remote study of elusive animals by recording high resolution movement data. Machine learning (ML) is common for automatic classification of behaviour from large data sets. To present a frame work for programming bio-loggers, the impact of sampling frequency on classification of behaviours was assessed.

Behavioural ethograms (swim, rest, chafe, burst and headshake) were developed for juvenile lemon sharks (*Negaprion brevirostris*) by observing sharks equipped with accelerometers during semi-captive trials at Bimini, Bahamas. Observations were used to ground truth data for ML. A random forest (RF) algorithm was developed to test a range of sampling frequencies.

Best overall classification was achieved at 30 Hz; however 5 Hz was appropriate for classification of swim and rest. Behaviours characterised by complex movements (headshake, burst, chafe) were not classified as well as swim and rest; classifier performance was best at 30 Hz.

Implications for classification of shark behaviour are discussed. These findings enabling us to refine classification of shark behaviour from bio-logging tools in the future.

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Scent and sensibility: EE2 disrupts male mate choice in fish

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Publish consent withheld

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Sex on steroids

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TBC

The depths of winter.

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Like most cold-blooded creatures, fish are less active in the winter, as their metabolisms dips, and their need for oxygen and food decreases. While many fish will wait out the cold months, others at the extreme end of their temperature tolerance can find these conditions much more stressful. For example, survival of larval Murray Cod significantly decreased following water release from cold impoundments in Victoria. Juvenile fish also face the risk of predation, particularly when they are less active over winter. The risk of predation however, can be dampened by the availability of shelter. The quantity and quality of habitat has been shown to significantly influence the survival of juvenile fish, as they seek shelter over winter. There is however, a significant gap in our understanding of fish habitat preference and behaviour in lakes over winter. I propose a project using remotely operated vehicles (ROVs) to describe behaviour, habitat use, and location of freshwater fish in lakes across Victoria over winter. This project will fill a gap in our fundamental understanding of what fish do, and where fish go, when the temperatures drop, and provide valuable information for habitat restoration management in Victorian lakes.

Predation drives recurrent convergence of an interspecies mutualism

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Mutualisms are important ecological interactions that underpin much of the world's biodiversity. Predation risk has been shown to regulate mutualism dynamics in a number of species-specific case studies. Surprisingly, however, we lack studies which investigate whether selection by predators can also explain broader patterns of mutualism evolution. We report that fish-anemone mutualisms have evolved on at least 48 independent occasions across 16 fish families over the past 60 MY and that adult body size is associated with the ontogenetic stage of anemone mutualisms: larger-bodied species partner with anemones as juveniles, while smaller-bodied species partner with anemones throughout their lives. Field and laboratory studies show that predators preferentially target smaller prey, that smaller individuals more commonly associate with anemones, and that these relationships confer increased protection to small fishes. Our results indicate that predation is the most likely pressure driving the recurrent convergent evolution of fish-anemone mutualisms and suggest that similar ecological processes may have selected convergence in interspecies interactions in other animal clades.

How to count baitfish - the problem of too many fish

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When you have so many fish you can't see the reef, what is the point in trying to count them and how do you do it? This poster will highlight the value of data that sits between individual counts and presence/absence for species with high abundance but patchy distribution

The distribution, form and function of false eye-spots in coral reef fishes

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tbd

Production to predation - the trophic ecology of pelagic ecosystems in the western Tasman Sea

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Ocean fisheries are increasingly managed by satellite imagery of sea level and sea surface temperature, but the ecosystem basis to these oceanic habitats is unknown. Mesoscale eddies are common features off Australia's East coast, providing distinct oceanographic habitats, with the direction of their rotation having powerful biological implications. This research will link size-based ecosystems of the western Tasman Sea, with trophic level estimates based on nitrogen stable isotopes composition of the major functional groups, to determine the trophic ecology of each oceanic environment. Trophic ecology and function can be revealed by quantifying a set of numerical food web parameters established from the relationship between body size and trophic level, such as: food chain length, trophic efficiency, and predator-prey mass ratios. The results displayed elevated trophic levels and lower abundance in the anti-cyclonic eddy environment compared with the cyclonic eddy across the entire size-structured study community from mesozooplankton to midwater fish. Anticyclonic eddy environments also returned higher predator-prey mass ratios and decreased trophic efficiency. These ecosystem metrics further our understanding of the effect of coastal ocean warming off eastern Australia, while information on the biomass, productivity, and resilience of each ecosystem, will be used to improve fisheries management.

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Variation in fish communities and feeding behaviour in response to boat moorings and seagrass density in an urban estuary

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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 seagrass and fish. Initially, we surveyed 4 mooring locations in Sydney Harbour to understand whether the abundance and feeding behaviour of fish communities differed in close proximity to boat moorings, finding that abundance and bites increased with distance to moorings. At Manly Cove, where SFMs have been installed, we mapped seagrass density and later surveyed fish communities in relation to seagrass and nearby mooring types (swing or SFM). We found higher density of seagrass in close proximity to SFMs and that the influence of seagrass cover and mooring type varied among fish species. Therefore, implementation of improved mooring designs can increase seagrass density, resulting in wider ecological benefits.

1. Lanham BS et al. (2018) Altered fish community and feeding behaviour in close proximity to boat moorings in an urban estuary. *Marine Pollution Bulletin* 129: 43-51

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Does it matter who gets caught first? Behaviour selectivity of fishing

Clement Ng, John Morrongiello

Fishing harvest has long been known to induce strong selective pressures on phenotypically desirable animals. The artificial selection of traits (e.g. size-selective harvest or targeting of spawning aggregations) differentially increases the risk of mortality for a specific phenotype, which in turn can result in life history changes within populations and altered food webs across community assemblages.

Behaviour is known to confer fitness advantages to an individual under a particular set of environmental conditions. For example, bolder individuals can have increased foraging efficiency or reproductive output, but with potential increases in predation or harvest risk. However, the effect of behavioural selectivity of fishing is poorly understood due to the challenge of drawing inferences about the cognitive mechanisms operating in wild animals. In this study, we investigate how size-selective fishing can impact on behavioural, morphological and physiological traits. In particular, we document how individual catchability relates to boldness, burst swim speed and fin aspect-ratios within and across three generations of zebrafish exposed to either sigmoidal or random size selection. The results from our study will be discussed in terms of the potential consequences of harvest-induced selection for sustainable fishery management within and across populations.

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Age, growth and mortality of tailor (*Pomatomus saltatrix*) in eastern Australia

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Pomatomus saltatrix (tailor) is a globally distributed pelagic mesopredator with previously identified differences in life history patterns. Despite being a key recreational species and subject to high fishing pressure in eastern Australia, many characteristics of *P. saltatrix*'s life history remain undefined. Over 3 years, Over 3,500 fish were sampled from recreational and commercial fishers across two jurisdictions. Annual formation of rings within otoliths was validated and whole otoliths were shown to be equivalent to sectioned otoliths. Growth was determined to be fast yet the oldest collected fish was 6 years old, suggesting possible age truncation of this stock as other populations of the same species are commonly caught at older ages. A global comparison of life history was conducted and growth rates were found to be similar between most global populations except the northwest Atlantic population which show faster growth and old age structure than the other populations. It is speculated that this difference in life history is due to differing natural mortality.

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Inside the otolith: the proteome of the fish inner ear

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Otoliths, the biomineralized stones in the inner ear of fish, grow continually throughout the whole of an individual's life – from embryo to death. Functionally, otoliths play a role in maintaining balance and proper hearing. As they are largely metabolically inert, they can be treated as a “black box”, recording the specifics of the physico-chemical environment experienced by a fish at any given point in its life. As a result, they are routinely used to reconstruct both growth and environmental histories. Currently, the biomolecular mechanisms that underpin otolith formation, growth and composition are largely unknown, as fewer than a dozen otolith proteins have been described. To address this shortcoming, we created a tissue-specific transcriptome for the inner ear and brain of a southern Australian fish, black bream (*Acanthopagrus butcheri*), which was used to identify proteins in proteomic data for otoliths and endolymph (inner ear fluid) from adult fish. We identified more than 350 proteins present in the otolith, revealing the potential mechanisms for how otolith nucleation occurs, the controls on daily increment deposition, the likely metal incorporation sites in the organic matrix, and the evidence, at the biochemical level, for their metabolic stability.

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

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- TBC

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Conferred feeding efficiency benefit in Caribbean tube sponges from sponge-dwelling goby

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Goby species interact and maintain long-term associations with sponges. Sponge-dwelling gobies benefit from protection within sponge tubes by using them as microhabitats. Although sponges are hypothesized to benefit from gobies consuming polychaete parasites or clearing sediment from filtering tissue, which improves their pumping rates, increases in pumping efficiency have not yet been demonstrated. Here, we investigated goby associations with two sponge species with similar tube morphologies (*Aplysina lacunosa* [convoluted barrel sponge] and *A. archeri* [stove pipe sponge]) in Bonaire, Dutch Caribbean. We visually assessed yellowline goby, *Elacatinus horsti*, presence in sponges. Then, we used *in situ* methods with fluorescein dye to estimate pumping rates by analyzing videos of dye front movement in tubes attached to sponges. There was a higher frequency of gobies in *A. archeri*(46%) than in *A. lacunosa* (26%) sponges. For *A. archeri*, pump rates were higher for longer sponges but size did not affect pump rates of *A. lacunosa*. For both sponge species, pump rates of tubes with gobies were significantly higher than those of tubes without gobies ($p < 0.05$). Therefore, these goby-sponge associations, and perhaps others, are likely mutualistic relationships in which sponge hosts benefit from higher feeding rates when gobies are present.

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Oxygen consumption profiles and critical oxygen concentrations indicate distinct hypoxia tolerance in selected closely related New Zealand native galaxiids

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The closely related New Zealand native galaxiid species inanga (*Galaxias maculatus*), banded kokopu (*Galaxias fasciatus*) and black mudfish (*Neochanna diversus*) inhabit distinct oxygen environments and have been shown to exhibit species-specific hypoxia sensitivities. To investigate whether these differences were based on distinct metabolic oxygen demands, oxygen consumption profiles as a measure of routine metabolic rates at normoxia, mild and severe hypoxia were determined utilising intermittent-flow respirometry. Inanga demonstrated the highest average oxygen consumption at normoxia and mild hypoxia ($14.7 \pm 0.6 \mu\text{mol O}_2 \text{ h}^{-1} \text{ g}^{-1}$) and black mudfish the lowest ($7.6 \pm 0.8 \mu\text{mol O}_2 \text{ h}^{-1} \text{ g}^{-1}$). All three species were indicated as oxyregulators. Inanga displayed the highest hypoxia sensitivity with a critical oxygen concentration (C_{crit}) of 5.0 mg L^{-1} , while banded kokopu were slightly more tolerant (4.3 mg L^{-1}). No C_{crit} was ascertained for black mudfish and it was deduced that they had a distinct tolerance towards hypoxia. The hypoxia sensitivities of the three species indicate species-specific metabolic oxygen demands and physiological response capacities. Therefore, habitat preferences of these species are likely a result of adaptive radiation processes in the context of the oxygen environment.

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Ageing gracefully: Determining the age of fish around Heard Island and McDonald Islands on the Kerguelen Plateau

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Over 25,000 fish caught in the Australian toothfish and icefish fisheries around Heard Island and McDonald Islands on the Kerguelen Plateau have been aged from sectioned otoliths in the Australian ageing program since 1999, comprising more than 45,000 individual reads from seven different readers. The majority of fish aged are Patagonian toothfish, *Dissostichus eleginoides* ($n = 23,770$), however the age structure of a number of bycatch species, including grey rockcod, *Lepidonotothen squamifrons* ($n = 1011$), unicorn icefish, *Channichthys rhinoceratus* ($n = 397$), and grenadiers, *Macrourus caml* ($n = 346$) and *M. carinatus* ($n = 300$), have also been examined. The resulting age data are used in stock assessments for target and key bycatch species, as well as in investigations of age-related biological and ecological characteristics that are important in understanding the fish dynamics across the Kerguelen Plateau. We also present spatial distribution (actual and modelled) of *D. eleginoides* ages on the plateau.

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Genetic differentiation and population structure of gizzard shad *Konosirus punctatus* in Korea and Japan

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The gizzard shad *Konosirus punctatus* is a fish that is a member of the herring family, *Clupeidae*, which is native to the estuarine regions of Korea, and distribution of this species is in the coastal areas of Eastern Asia, including China, Japan, Taiwan, and Hong Kong. Previous study reported that there are two distinct mitochondrial lineages of *K. punctatus* around Korean and Japanese coastal waters: Lineage A was only distributed around Korean coastal waters and dominates the West Sea and South-West Sea group of Korea. While Japanese groups of *K. punctatus* were exclusively assigned to lineage B. To investigate how genetic differences influence the outcome of secondary contact, genetic polymorphism in Gizzard shad, collected from wild populations of six locations in Korea and four locations in Japan, were examined using eight microsatellite loci, which were developed for the present study. Consistent with previous results, we find distinctive population structure of *K. punctatus* between Korea and Japan. The results of msDNA reveals that genetic exchange have been existed on the sympatric zones of both lineages in southeast and east coasts of Korean coastal waters. Consequently, the results from the present study will be useful for effective management of this species.

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Australasian fishes an online resource for everyone.

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Fish researchers and the general public are discovering Australasian Fishes. This online citizen science project gives users access to over 36,000 observations (data points) of Australian and New Zealand fish records, each with one or more photographs. The site has been online for less than two years but has had contributions from over 1100 users with coverage of 2000 species. The site can be queried by taxa or locality and the data displayed as gallery of photos, dot points on a map or as

a list. You can set your account to receive email notifications of observations from targeted localities and/or taxa of interest. If you wish, you can easily set up a new project for your own research that can feed into the larger Australasian Fishes project.

1. <https://www.inaturalist.org/projects/australasian-fishes>

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Performance of Australian fisheries relative to target objectives

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Abstract: An increasing number of fisheries within Australia are being managed under harvest strategies. These often aim to maintain stocks at or near a target reference point (TRP) and minimise the probability of stocks falling below a certain level or limit reference point (LRP). A number of sustainability classification schemes have been developed which designate stocks as sustainable if they are at or above the LRP. This can lead to a performance gap whereby some groups will consider a sustainable classification as sufficient evidence that a stock is well managed, even when the stock is not at or near levels targeted by management. Using the Status of Australian Fish Stocks, a national fisheries performance reporting platform, this study explores this 'performance gap', collating those species that contain an estimate of stock biomass relative to unfished biomass and comparing this against its assigned TRP. If an explicit TRP has not been defined, a proxy TRP will be assigned. This study will provide an assessment of Australian fisheries performance in terms of maintaining stocks at target levels rather than merely being sustainable.

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Business as usual for the human use of Moreton Bay Marine Park

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The multiple-use Moreton Bay Marine Park in eastern Australia was rezoned in 2009, increasing the total no-take marine national park (MNP) from 0.5 to 16%. We measured trends in the human use of no-take areas using observed vessel position and categorisation during on-water and aerial surveys before and after rezoning. Measured changes in spatial patterns of fishing showed that the effects of rezoning on most fishing activity was minimal. After rezoning, the proportion of recreational fishing declined from 6.3 to 2.6% of the footprint of the new MNPs and adjacent areas of similar habitat. The proportion of commercial fishing declined from 25 to 1%, although the amount of commercial fishing was low.

Observations of 397 individual marine national parks were made using boat-based surveys conducted in paired MNP and control areas. The surveys were followed up by 200 interviews with Moreton Bay users. The majority of the boaters interviewed (56%) didn't believe their activities would be, or had been, affected by new MNP zones. However, 40% of boaters interviewed said the MNP zones had affected their fishing activity, despite our research showing only 6% of recreational fishers had actually fished in MNP zones prior to the new zoning being declared. A significant majority (65%) of interviewees felt the rezoning would be 'positive for the biology' of Moreton Bay.

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Australian fisheries management system

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Where have we been, where are we going? 10 years into the recovery of an important demersal scalefish resource in Western Australia.

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The first West Coast Demersal Scalefish Resource stock assessment of indicator species WA dhufish, pink snapper and baldchin groper was completed in 2007. This stock assessment concluded that overfishing of the stocks was occurring and that the levels of fishing mortality by all sectors needed to be reduced by at least 50% to allow stocks to recover. Between 2008 and 2010, significant management action was introduced with the management objective of maintaining total retained catch and effort by all sectors below 50% of 2005/06 levels to recover the resource within 20 years.

In 2017, the Department of Primary Industries and Regional Development completed the latest stock assessment of the resource. This assessment indicated that there were signs of early recovery in some management areas however the expected rate of

recovery in some management areas was not being achieved due to previous or current high catches and high levels of releases and associated post-release mortality

Now, ten years since the first stock assessment and halfway into the original recovery plan, the effectiveness of the current management objective is able to be reviewed to adapt to changes in fisher behaviour and ensure the resource is able to recover in the appropriate timeframe.

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Field Manuals for Sampling to Monitor Australian Waters

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Australia is uniquely placed to develop standardised national approaches to monitor the marine environment, and we have therefore released a suite of field manuals for the acquisition of marine benthic data so that data are directly comparable in time and through space. The manuals include selected frequently-used sampling platforms: Multibeam sonar, autonomous underwater vehicles, baited remote underwater video, towed cameras, grabs and box corers, and sleds and trawls. The main challenge in the development of these manuals was to find a balance between being overly prescriptive (such that people follow their own protocol, ignoring the manuals) and overly flexible (such that data is not consistent and comparable). A collaborative approach was paramount, and ultimately, over 65 individuals from 30 organisations contributed to the field manuals. This not only improved the content but also increased the potential for adoption across multiple agencies and programs. Future work is based on the understanding that sampling protocols should be periodically updated, lest they become superseded or obsolete. Version 2 of the field manual package is due for completion in late 2018, including potential new manuals and a long-term plan for their management and integration into a national Australian monitoring program.

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Coping with Climate Change: effect of dietary fat content on the thermal tolerance of barramundi

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Aquatic organisms, including important cultured species, are subject to acute changes in water temperature as the frequency and intensity of extreme weather events worsen. Acute temperature spikes are likely to threaten aquaculture productivity, but dietary intervention may play an important protective role. Therefore, this study used two commercially available diets (20% crude fat versus 10% fat crude fat) to examine if dietary fat content can improve growth performance in juvenile barramundi (*Lates calcarifer*) while increasing their resilience to acute thermal stress. Fish were fed their assigned diets for 28-days before assessing the upper thermal tolerance (CT_{MAX}) and the thermal sensitivity of swimming performance and metabolism. We found that feeding fish a high fat diet resulted in heavier fish, but did not affect the thermal sensitivity of swimming performance or metabolism over an 18°C temperature range (from 20 – 38°C). Thermal tolerance was compromised in fish fed the high fat diet by 0.48°C, showing significantly lower CT_{MAX}. Together, these results suggest that while a high fat diet increases juvenile *L. calcarifer* growth, it does not benefit physiological performance across a range of relevant water temperatures and may even reduce fish tolerance of extreme water temperatures.

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How regional fishery bodies have responded to climate change

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This is the first global survey of Regional Fishery Bodies (RFB) responses thus far to the current and predicted future effects of climate change. Fisheries management is highly dependent on the regularity in space and time, within ecological boundaries, of targeted fish populations. Oceanic climate-driven changes are leading to continuing deviation from this regularity. Around the world ocean are areas of measurably faster warming sea surface temperatures, 'hotspots', which can provide potentially strong indicators of the direct effects of climate change. We assessed the annual reports of 17 RFB over the period 2002 – 2016, looking for the phrase 'climate change' and the context in which the phrase was used. Three levels of institutional engagement were developed: Awareness of climate change; Learning about climate change; and then any Action taken by the RFB. Of the RFB examined, 88% of institutions demonstrated awareness of climate change; 82% demonstrated learning about climate change; while only 41% demonstrated some form of action, but these were mainly procedural and administrative. Over the last 14 years, the gap between 'awareness' and 'action' was actually growing, i.e. awareness was increasing steadily and yet action remain stagnant. Only two of the RFB examined made explicit statements about incorporating climate change into future fishing

management plans. The inference is that most RFB are largely practicing business-as-usual, with the implication that fish populations under industrial fishing will continue to experience maximal fishing effort as the sea around them alters.

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Physical trade-offs shape the evolution of buoyancy control in sharks

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Buoyancy control is a fundamental aspect of aquatic life that has major implications for locomotor performance and ecological niche. Unlike terrestrial animals, the densities of aquatic animals are similar to the supporting fluid, thus even small changes in body density may have profound effects on locomotion. Here we analysed the body composition (lipid vs lean tissue) of 32 shark species to study the evolution of buoyancy. Our comparative phylogenetic analyses indicate that although lean tissue displays minor positive allometry, liver volume exhibits pronounced positive allometry, suggesting that larger sharks evolved bulkier body compositions by adding lipid tissue to lean tissue rather than substituting lean for lipid tissue, particularly in the liver. We revealed a continuum of buoyancy control strategies that ranged from more buoyant sharks with larger livers in deeper ecosystems to relatively denser sharks with small livers in epipelagic habitats. Across this eco-morphological spectrum, our hydrodynamic modelling suggests neutral buoyancy yields lower drag and more efficient steady swimming, whereas negative buoyancy may be more efficient during accelerated movements. The evolution of buoyancy control in sharks suggest that ecological and physiological factors mediate the selective pressures acting on these traits along two major gradients, body size and habitat depth.

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Cryptic habitat use of white sharks in kelp forest revealed by animal-borne video

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Traditional forms of marine wildlife research are often restricted to coarse telemetry positions or surface-based observations, limiting information on fine-scale behaviours such as predator-prey events and interactions with habitat features. We use animal-attached cameras with motion sensor loggers, to reveal novel behaviours by white sharks, *Carcharodon carcharias*, within areas of kelp forest in South Africa. All white sharks tagged in this study spent time adjacent to kelp forests, with several moving throughout densely kelp-covered areas, navigating through channels and pushing directly through stipes and fronds. During over 21 hours of video data, white shark encounters with Cape fur seals, *Arctocephalus pusillus pusillus*, occurred exclusively within kelp forests, with seals displaying predator evasion behaviour during those encounters. Uniquely, we reveal the use of kelp forest habitat by white sharks, previously assumed inaccessible to these large predators, redefining our understanding of their foraging and movement strategies.

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Hydrology drives fish condition comparison of a wet dry tropical river with an arid zone river

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Hydrology is an important driver of connectivity of fish stocks, and availability of habitat for feeding and reproduction. In the wet-dry tropics, unregulated rivers may flood in the wet season, creating floodplains for fish feeding and reproduction. During the dry season, many rivers cease to flow, and fish must survive in disconnected waterholes with diminishing resources. However, there has been little research on how these hydrological extremes in wet-dry tropical rivers affect fish production in comparison with other river systems. We measured fish biomass and condition in isolated perennial waterholes in the Flinders River catchment, Queensland throughout a dry season. We found that fish biomass decreased over the dry season as waterholes contracted, likely reflecting resource limitation and predation. The Flinders system had similar species composition to an arid zone river in central Australia, Cooper Creek. However, the key difference was that the arid zone river had more extreme 'boom and bust' periods of flow (and fish dynamics), while the Flinders system had more consistent inter-annual hydrological patterns. Fish in both systems are pre-adapted to these variable conditions so in both cases, there is a need to preserve natural flows to maintain fish productivity and diversity.

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Investigating habitat values of *Halophila ovalis* and *Chaetomorpha linum* in the Swan-Canning Estuary

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Seagrasses often provide important ecosystem functions, including providing nursery habitats for economically important fishes. *Halophila ovalis* is the most abundant seagrass in the Swan-Canning Estuary, Western Australia, where macroalgal blooms, particularly *Chaetomorpha linum*, can result in seagrass loss. In this study, fish were sampled using a seine net in *H. ovalis* meadows, floating *C. linum* and bare sand, as well as floating detached vegetation, to compare their habitat value for fish communities in the estuarine system. Differences in fish communities across habitats were often dependent on location in the system. Generally, vegetated habitats had different fish communities to each other and to bare sand. During the day, *H. ovalis* generally had higher abundance and species richness than bare sand, whilst bare sand contained more fish and species than *C. linum*. At night, bare sand had higher abundance and species richness than *H. ovalis*. Floating detached vegetation had higher abundance and species richness than bare sand. This suggests that these vegetated habitats play a role for fish in the system, but the findings are not consistent across locations, which may relate to extreme rainfall immediately preceding the study period or other environmental factors.

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Moving numbers: innovative models for fish telemetry

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The advent of modern telemetry methods have resulted in a vast increase in the volume of movement data being collected. What do we do with all this data, and how can we use it to answer actual questions of ecological and evolutionary interest? I argue that some studies still just ask the question: 'did the fish cross the road?' when in actual fact the key question is 'why did the fish cross the road?'. The application of not-too-complex analytical techniques to telemetry data can greatly increase our understanding of the drivers and relevance of fish movement. Here, I introduce a series of mixed models, illustrated with examples, to show how greater biological insight can be garnered from the vast data archives at hand. Properly harnessing the potential of data collected in telemetry studies will greatly increase our ecological and evolutionary understanding of the causes and consequences of animal movement.

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Social licence and citizen science: Potential and progress

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Social licence is an emergent concept in the marine sector and has become an important theme for development in marine industry and resource use, particularly in the context of exploring communication and stakeholder engagement. At the same time, meaningful public and societal engagement with science and research is increasingly recognised as necessary to advance public knowledge about the marine environment and to promote stewardship of ocean spaces. Citizen science is a diversified phenomenon that is expanding rapidly in marine spaces and may create pathways for support between social groups and promote networks for collaborative decision making that can enhance outcomes for science and management. Our research is among the first attempts to link social licence theory with citizen science, aiming to produce actual practical outcomes that can be applied in ocean management. Here, we examine the role marine citizen science can play in promoting social licence in the marine realm. Firstly, through an exploration of European citizen science projects and their potential to enhance social licence for marine conservation. Secondly, we describe an Australian case-study highlighting whether diverse participant groups (i.e. divers, fishers) construct and exchange opinions via this platform and whether social licence is promoted or withheld through such exchange. We outline the potential role of social licence as a tool to foster positive engagement between marine user groups, and identify how citizen science may influence perceptions and promote social licence in the marine realm.

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Carpooling – carp removal during infrastructure upgrades in Canberra

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In 2017 the ACT Government as part of its Healthy Waterways initiative undertook the draining of two urban ponds in Canberra. The draining was required for a replacement and upgrade of a weir and to facilitate the construction of water quality control infrastructure. The National Carp Control Plan (NCCP) requires understanding of total biomass of carp and the relation to regular monitoring to allow development of biomass and epidemiological models and planning for clean-up. The draining of these ponds was an opportunity to accurately quantify carp biomass and gain an insight into these values to existing monitoring of other ACT water bodies and assist other NCCP research.

Prior to the draining, monitoring was undertaken following standard electrofishing protocols. Removal of the Carp and other fish in the ponds was done manually over three days for each pond as they were approaching empty. Subsamples of Carp were measured for length and weighed with a total of 5 tonnes of Carp were removed across two ponds.

Pond refilling is being followed by restocking with native fish and additional habitat enhancement in both ponds with significant drops in turbidity already observed in the first pond to refill.

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Comparison of catch rates and catch composition among research-angler diary and fishery-independent survey methods

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Research-angler diary (RAD) and fishery-independent survey (FIS) methods were trialled to sample recreational fish populations of black bream (*Acanthopagrus butcheri*) in Gippsland's Lake Tyers. Catch rates and catch length-frequency distributions were compared between these methods. The FIS method consistently caught significantly more species of fish and much higher numbers of fish than did the RAD method. The higher catch rates for the FIS method than for the RAD method for fish of length \geq LML are explained by higher 'encounterability', whereas the much higher catch rates for fish of length $<$ LML are explained by the combination of higher 'encounterability' and much higher 'selectivity' of the fishing gear. The FIS (beach seine) catch rate and catch length-frequency composition provided reasonably unbiased indices of relative abundance and length-frequency distribution. Conversely, apart from the smallest fish in the population (too small to catch during the trials), the RAD method could not be applied as an indicator of the relative strength of length classes or cohorts in the population without adjustment for the effects of species-specific length-selectivity.

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The boy can dance: Ritual courtship of the Opal cling goby

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Despite extensive research into the reproductive biology of amphidromous sicydiine gobies, there have been few detailed reports of courtship behaviour exhibited by representatives of this group of fishes. The standout exception is the comprehensive field based research of *Sicyopterus stimpsoni* in streams of the Hawaiian Islands. There have also been studies of reproduction biology including brief mentions of male-female displays and male-male territorial displays of *Lentipes concolor* and the temperate *Sicyopterus japonicus*. In the current study, phases of courtship display are described from opportunistic observations and filming of spectacular ritual courtship of the Opal cling goby, *Stiphodon semoni*, in the Australian Wet Tropics. This new information is used to enhance thinking about courtship behaviour in sicydiines, and the experience is used to comment on different forms of observer effect. These recent behavioural observations are also cast as important in reinforcing local protective and conservation status of this species in Queensland and Australia.