Fostering strategic fisheries management responses to Australia's changing climate

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Tables

Acknowledgments

This project report concludes a major joint initiative in assessing how Australia might best adapt to a changing climate. This adaption is to deliver benefits for marine biodiversity and fisheries and all those engaged in these sectors of the Australian economy. Major investors in the $9M RD&E program were FRDC, the then Department of Climate Change and Energy Efficiency, the Department of Agriculture, Fisheries and Forestry, State Government agencies in South Australia, Tasmania, Victoria and NSW, CSIRO and several universities.

For this component of the initiative resources were provided by FRDC. I am indebted to the support and contribution of my co-authors in the two science papers – Prof Marcus Sheaves, Dr Paul Boon, Prof Justin Brookes, Dr Alistair Hobday, Assoc. Prof Michael Lockwood and Dr Gretta Pecl; to co-workers in developing the series of summary fact sheets – Dr Alistair Hobday, Dr Gretta Pecl and Dr Beth Fulton; to Dr Patrick Hone for communicating the Program's findings to the Australian Fisheries Management Forum; to the FRDC staff, especially Annette Lyons, Pele Cannon, Peter Horvat, Ilaria Catizone and Crispian Ashby for support in program management and communication / extension and to Dr Gretta Pecl, Dr Tim Ward and Dr Stewart Frusher for organising and undertaking the various interactions with fishers and coastal communities.

Abbreviations

AFMF – Australian Fisheries Management Forum

CSIRO – Commonwealth Scientific and Industrial Research Organisation

FRDC – Fisheries Research and Development Corporation

IMOS – Integrated Marine Observing System

NERP – National Environmental Research Program

NESP – National Environmental Science Program

Executive Summary

This report summarises work completed as a sub-project to the Climate Change Adaptation – Marine Biodiversity and Fisheries Science Program. This program was a joint investment between the Fisheries Research and Development Corporation, the then Department of Climate Change and Energy Efficiency, the Department of Agriculture, Fisheries and Forestry, State Government agencies in South Australia, Tasmania, Victoria and NSW, CSIRO and several universities.

This sub-project was undertaken to conclude activities arising from the completion of the Program. Particularly, there was a need to capitalise on the information and knowledge generated from the suite of projects undertaken within the Program, and ensure that key findings were communicated. Three key groups were identified in the project plan as key targets for this knowledge exchange:

- senior fisheries managers and policy makers;
- fishing industry and broader community
- science community

By maximising returns from research already undertaken, through enabling this communication strategy, the FRDC sought to assist agencies, policy makers and the community in their negotiation of climate change related information: dispel myths and misinformation, and foster preparedness amongst all sectors in the process of adapting to a changing climate.

This project was structured under four objectives:

Objective 1: Smarter fisheries management – provide the information to foster an improved understanding of the implications of climate change on fisheries stocks, fishing effort and marine biodiversity, thereby providing input into Australian and state based fisheries management and policy.

Objective 2: Repaired more productive and resilient inshore habitat – building on the climate adaptation imperatives of resilience and carbon sequestration opportunities for inshore habitat together with the opportunities of *Direct Action*, foster works and activities that will ensure increased inshore productivity for professional, recreational and indigenous fishers and marine biodiversity.

Objective 3: Increased investment in knowledge generation – articulate the benefits of resourcing R&D for the key knowledge gaps across climate adaptation, carbon sequestration and inshore fisheries habitat and seek for FRDC co-investment partnership arrangements with key Australian Government agencies

Objective 4: Maximise science quality, outputs and dissemination of existing investments – review and evaluate to ensure a high standard of all draft milestone and draft final reports, remaining projects.

These objectives were met while recognising in the first 3 objectives much remains to be done. Certainly the information has been provided to underpin smarter fisheries management. Repairing habitat is an ongoing task and with some significant steps achieved in the period of this project. The opportunities for further R&D have been detailed and for Objective 4, the program and all its component projects together with summary science papers have been completed to a high quality.

Structuring delivery against the joint investment as a Science 'Program' allowed for consistency across the design, conduct, selection and scientific management of the specific science projects, maximising return on investment. This sub-project consolidated the extension of the knowledge generated by the Program through activities such as presentations to key forums, the preparation and distribution of fact sheets, and multiple face-to-face discussions from senior policy makers through to various marine users. This allowed for the wide sharing of the findings of the Program, and outlined how the various groups may best apply the findings to their specific issues and needs.

Unfortunately, this project of consolidation and extension was undertaken in a period of rapidly changing national climate policy, as demonstrated by the abolishing of many of those Federal and State government agencies or units taking a lead role on climate policy during the period of this project, and by the diminishing more generally of resources available for science and innovative policy formation.

Nevertheless, the conclusion of the Climate Change Adaptation Program – Marine Biodiversity and Fisheries allows for a concise reflection on the successes and challenges of instituting, delivering, managing and extending a major body of scientific investigation. This report provides several recommendations based on these learning's.

Keywords

climate change adaptation; marine biodiversity, fisheries, ecosystem resilience, habitat repair

Introduction

The Fisheries Research and Development Corporation has a dual remit to provide knowledge that will deliver both:

- public benefit marine protection and management; and
- private benefit profitable and sustainable use of marine resources – professional and recreational fisheries, aquaculture and indigenous take.

FRDC took the initiative to coordinate, integrate and lead a range of marine climate adaptation and mitigation-related investments, recognising the worth of consolidating such projects under the management of a single Program. This includes through this project investing to ensure that priority knowledge gaps are met, that there is close interactions and cross-overs in learning's between the research providers, and that all findings were translated into products to meet the knowledge needs of various user groups in ways that might foster adoption. User groups range from policy makers to marine managers to marine users such as fishers and conservation groups.

Tables 1 & 2 in the companion FRDC report [Creighton, C 2014 a)] provides a summary of the investment and a conceptual framework of how the program was designed and projects were selected to deliver to the various needs and hierarchies of marine biodiversity and fisheries management.

All projects were managed under standard contracts against agreed sets of milestones. Milestones were required to include research updates. These updates were reviewed for science quality and the findings as the projects progressed were communicated widely. Communication outputs required of all projects included:

- submission of science papers to peer-reviewed journals;
- management and repository of any data generated within the Integrated Marine Observing System (IMOS); and
- preparation of summary findings and presentations such as fact sheets or articles for 'Fish' or other newsletters for broad distribution, especially for end users.

These three broad areas of communication, also included by each project team in a Communication Plan, ensured that project by project findings were communicated to those with substantial interest in specific project findings. Final reports for all projects were progressively quality assured, and uploaded on to the FRDC website, provided to libraries, work shopped through with specific end user groups and presented to peer groups at various conferences. Again this was done project by project.

This report is about the entire program. This sub-project resourced the task of ensuring all key across-Program findings were made readily available to relevant policy makers, managers, fishers and the broader community through a range of media and formats.

Objectives

The Objectives of the sub-project, as agreed and documented in the contract were:

Objective 1: Smarter fisheries management – provide the information to foster an improved understanding of the implications of climate change on fisheries stocks, fishing effort and marine biodiversity, thereby providing input into Australian and state based fisheries management and policy.

Objective 2: Repaired more productive and resilient inshore habitat – building on the climate adaptation imperatives of resilience and carbon sequestration opportunities of inshore habitat together with the opportunities of *Direct Action*, foster works and activities that will ensure increased inshore productivity for professional, recreational and indigenous fishers

Objective 3: Increased investment in knowledge generation – articulate the benefits of resourcing R&D for the key knowledge gaps across climate adaptation, carbon sequestration and inshore fisheries habitat and seek for FRDC co-investment partnership arrangements with key Australian Government agencies

Objective 4: Maximise science quality, outputs and dissemination of existing investments – review and evaluate to ensure a high standard of all draft milestone and draft final reports, all remaining unfinished projects.

Each of these Objectives led to a stream of work, separate but inter-linked as detailed in the combined Methods – Results - Discussion section. Detail is presented within the three broad client groups listed in the project plan:

- senior fisheries managers and policy makers;
- fishing industry and broader community
- science community

Methods, Results & Discussion

This sub-project was focused on ensuring the coordinated delivery of the *Climate Change Adaptation – Marine Biodiversity and Fisheries* science program's key findings. The suite of outputs against each of these target audiences was nominated at the start of the project within the project plan.

Outputs nominated were commensurate with the differing styles of knowledge exchange generally employed in communicating with each of these target audiences. The actual outputs achieved are then listed. These outputs varied over time and for audience and were all undertaken in a rapidly changing external policy and institutional environment. This affected the timing and nature of delivery of outputs and outcomes.

Key factors of the external environment that must be noted included:

- a rapidly changing policy environment for all matters relating to climate change;
- a rapidly diminishing availability of funds for research and development; and
- as a consequence, an overall environment that did not foster innovation in policy, management or investment

The sub-project had to rapidly respond to this changing environment. For all three target audiences additional and / or modified outputs to those initially nominated were delivered as part of this need to rapidly respond to the changing external environment. Reflections on the knowledge exchange process, what worked, what were the constraints and opportunities conclude each section on the three target audiences.

Target Audiences, Outputs & Progress Towards Knowledge Exchange

Target Audience 1 – Senior fisheries managers and policy makers

Outputs Nominated

Outputs nominated at inception in the approved project plan were:

1.1 Climate Change Adaptation briefing papers. These were to cover:
- the implications of a changing climate for fisheries management and marine biodiversity knowledge needs
- opportunities to incorporate the implications of a changing climate in the next generation of fisheries management policy
- targeted action for multiple outcomes – inshore fisheries habitat repair

1.2 Summary PowerPoint presentations being for FRDC to use:

- for broad discussion at AFMF
- for use by AFMF members in their jurisdictions
- for discussions with senior agency policy makers, especially around the various opportunities for *Direct Action* and natural resource management investment

1.3 Submissions and representations to each step of the proposed Emissions Reduction Fund and revised Carbon Farming initiative:

- Terms of Reference [out till mid Nov 2013]
- Green Paper [due mid December]
- White Paper [due early to mid 2014]

Summary of Outputs actually delivered

In brief these included:

- Accompanying Program Report titled *Marine Australia – Directions for management and future research*, widely circulated electronically and uploaded on the FRDC website;
- PowerPoint presentations for use by FRDC in various forums, including such as AFMF;
- Briefing Papers, being shortened extracts from *Marine Australia – Directions for management and future research* and then used at several senior forums, especially science forums and available for FRDC to use at forums such as AFMF;
- Detailed submissions to each phase of the *Direct Action* process;
- Reworking of the entire Climate section of the FRDC website to better reflect the current policy and institutional environments as well as the emerging knowledge needs for all those likely users of the FRDC website;
- Personal interactions with political leaders and their staff and senior agency policy makers on the developing policy of *Direct Action;*
- Personal interactions with political leaders and their staff and senior agency policy makers on the role of fisheries habitat repair as a key first off strategy to minimise the impacts of a changing climate by increasing system resilience;
- Formal submission and personal interactions with lead agency representatives to assist in the formative phases of the Great Barrier Reef Trust, now known as "Reef Trust"; and
- Preparation of a 2 page briefing paper titled *Repairing Estuary and Inshore Productivity* and various face to face and phone conversations with political leaders and with senior managers responsible for the National Environmental Science Program.

Reflections on outputs delivered and their role in fostering engagement and improved knowledge

All these outputs to senior managers and policy makers were delivered in a rapidly changing policy, institutional and funding environment. The Australian Government and those states that had specific agencies / groups leading policy on climate change disbanded many of these agencies / groups. Climate and climate change as an issue tended to polarise the Australian community with the language of debate more about faith [believers and deniers] than about the facts and the quality of the science evidence underpinning them.

The most significant impact of this restructuring, across all jurisdictions, was a tightening of the available resources for both initiatives and current activities. Novel and innovative concepts such as an investment in habitat repair for blue carbon outcomes or long term policy development such as changing the way we manage fish stocks across jurisdictions is always constrained and is often perceived as lower priority with preference given to areas of immediate need when resources are limited and the concepts of climate change are not universally understood or require longer time frames for implementation.

Australia-wide policy initiatives such as the National Climate Change Action Plan for Fisheries and Aquaculture had their resourcing reallocated to other emerging policy areas. The revised National Environmental Science Program [NESP], previously known as the National Environmental Research Program [NERP], was also substantially constrained in available resources. Constrained resources meant that essentially only those existing very high priority National areas of interest, especially high international profile areas such as Antarctica and the Great Barrier Reef were likely to receive funding. While representations at Minister, Senator and Departmental officer level were made to seek support for R&D in both marine climate-related science and habitat repair science, due to the constrained nature of resources available, these representations were unsuccessful.

Direct Action is the Government's policy initiative to address issues of climate variability and change, especially from a mitigation perspective. Due to constrained resources, the bulk of *Direct Action* focuses on support for industry as it rightly works through ways and processes to reduce its greenhouse gas footprint. This is a clear area of guaranteed return on investment, well documented and in line with many similar initiatives internationally.

Regarding this sub-project, an extract of it's submission to the *Direct Action* Terms of Reference was cited in the following Green Paper. The Minister responsible also sought further clarification on the opportunities provided by "blue carbon". Nevertheless, the limited scope and resources available for the *Direct Action* initiative meant that a range of the more innovative policy opportunities for carbon sequestration were not able to be included in a resource-limited and somewhat politically controversial *Direct Action*. For "blue carbon" the other key factor that must be noted is that internationally, this is still a developing policy area.

Table 1 summarises activities from an Outcome perspective.

Table 1: Summary of Outputs and Outcomes achieved – policy & managers

Tasks	Outputs	Outcomes & Comments
Climate Change Adaptation briefing papers and summary PowerPoint presentations prepared.	Completed	Information provided to achieve an overview understanding Difficult to precisely attribute any changes in policy and management to the outputs. Have built a strong recognition among key players that climate, climate variability and to some degree climate change should be considered in formulating policy and management response.
Submissions and representations to each step of the proposed Emissions Reduction Fund and revised Carbon Farming initiative	Comments submitted and follow up face-to-face discussions.	Quoted in the Green Paper & follow up Ministerial level discussions. Knowledge awareness achieved. *Direct Action* scheme is principally targeted at the internationally recognised industrial scale polluters and their opportunities to mitigate.
Other Activities not listed in contract	Multiple interactions fostering improved awareness of the opportunities for smarter policy and management from both climate adaptation and resilience perspectives.	Knowledge awareness achieved Broad indications that policy and management will include resilience / repair. Climate issues, especially variability at most broadly incorporated in thinking as part of policy formulation and management proposals.

Target Audience 2 – Fishing [profes 'onal, recreational and indigenous] and broader community

Outputs Nominated

Outputs nominated at project inception were:

2.1 Summary information on the implications of climate change, especially from an adaptation perspective covering:

- PowerPoint presentations and summary information provided to FRDC for various annual general meetings, forums and specific port visits
- Input to the next CSIRO Marine Report card, especially the summary document and the summary's wide distribution to all jurisdictions

2.2 Short articles for newsletters

- Two articles in *Fish* – with one covering the implications of a changing climate on fisheries management and one covering the opportunities for *Direct Action* on inshore habitat repair.
- Foster the reprinting of these articles such has occurred with previous articles – e.g. NSW National Parks Journal
- Articles as updates within the Fish Habitat Network newsletter

Summary of Outputs delivered

In brief these included:

- Presentations, discussions and follow up at several recreational fishing forums – Victoria, NSW, South Australia and Western Australia
- A series of summary fact sheets that were made available electronically and also printed and disseminated that covered:
  - The entire initiative and its findings
  - Atlantis and the potential long term implications of a changing climate on fish stocks [FRDC 2010/023:Potential futures for Australia's south eastern marine ecosystems, quantitative Atlantis projections]
  - Stock by stock assessments and implications for the 4 key species investigated in the South East project [FRDC 2011/039: Preparing fisheries for climate change – assessing alternative adaptive options for four key fisheries in south eastern Australia]
  - Opportunities for improved productivity / profitability for the component industries covered in the Value Chain project [FRDC 2011/233: Growth opportunities and critical elements in the supply chain for wild fisheries and aquaculture in a changing climate]
- Providing information and supportive material for various port visits and community discussions, to be undertaken especially by Gretta Pecl, Tim Ward and Stewart Frusher and principally funded through FRDC 2011/039.
- Discussions and presentations with various agency and community groups, including:
  - Natural resources management groups – e.g. Reef Alliance, south west WA;
  - Floodplain management group, northern NSW;
  - Oceanwatch, including attending meetings accompanying Oceanwatch to meet with Senators and members of the House of Representatives;
- Articles in *Fish* including their reprinting in various other newsletters – conservation groups such as NSW National Parks Association, recreational fishing groups such as VRecFish and science community newsletters such as *RipRap* :
  - Blue carbon
  - Connectivity
  - Climate adaptation
  - Business case for investment in repair
- Articles in the Fish Habitat Network newsletter

- Work with recreational fishers and Victorian researchers and The Nature Conservancy on re-establishing shellfish reefs together with providing information to a range of interested parties across southern Australia, especially southern Qld, NSW, WA, Tas and SA.

Reflections on outputs delivered and their role in fostering engagement and improved knowledge

Habitat repair is one of the essential first steps in ensuring resilience in stocks to any shocks and changes that might occur through a changing climate. This concept of initially repairing water quality and habitat has been successfully used to gain resources in the Great Barrier Reef region since 2007-08. The initial $200M investment called *Reef Rescue I* was on the basis that we can rapidly repair water quality and it is within Australia's immediate control whereas climate change is an international issue.

The second investment of about $160M included $60M on habitat or as it is known in *Reef Rescue II* "systems repair'. Here the argument put, as in the previous FRDC commissioned work [FRDC 2012/036] was that repair of key physical habitat must accompany repair in water quality. Again this is as a precursor and basis for resilience to a changing climate.

Continuing in this successful process for investment in repair to fisheries and reef – lagoon environments an Investment Plan has now been released for actions to meet the targets in the joint Australian and Queensland Government's *Long Term Sustainability Plan – 2050.* This Investment Plan also delivers to the needs of the World Heritage Commission and their concerns that the Reef is possibly "in danger". To date the Qld Government has committed $100M towards this third tier of investment with Australian Government contributions yet to be finalised. The Investment Plan can be found at: http://www.rgc.org.au/wp-content/uploads/2015/01/Investment-Plan-NRM-proposal-190115.pdf . This author led the team that prepared this Investment Plan and built on the outputs of all the FRDC commissioned Climate and Habitat Repair research referred to in this report to ensure a strong evidence base to the Investment Plan.

In several states, notably NSW and Qld and to a lesser degree Victoria, reform processes in fisheries management are underway at the instigation of their state governments. Unfortunately aspects of these reform processes are polarising the attitudes and behaviours of some of the broader fishing community back into an "us or them" suite of responses. This is reinforcing once again the divide between professional and recreational fishers, and even divides within the professional sector. The appetite for partnership around habitat repair is reduced when it is perceived the agenda is more about competition and some form of resource competition between recreational and commercial sectors. While in several meetings the issue of a declining resource has been well documented as more the result of habitat lost than harvest, the polarisation of fishers is constraining the opportunities for cooperative effort. Clearly under such an environment of mistrust between the sectors and indeed mistrust also of Government agendas, there was not a very receptive environment to introduce changed management arrangements to account for and adapt to a changing climate.

Progress is being made in repair of shellfish reefs. Shellfish reefs provide habitat, especially multi-dimensional nursery areas, possibly spawning areas and equally importantly, massive in-situ biological nutrient assimilation systems. Under all the well-recognised Global Climate Models for a changing climate the predictions are that Australian coasts will experience a more variable climate, more extreme runoff events and therefore more sudden slugs of nutrients into our coastal receiving waters of embayments and estuaries. Re-establishing shellfish reefs will provide a first line defence against the deleterious effects of such events such as the increased threat of toxic algal blooms.

The Victorian Port Phillip pilot is already developing into a strong partnership between agencies, the recreational and professional fishing sectors and The Nature Conservancy. Investment committed to date exceeds $300K for the pilot. A parallel initiative with at this stage lesser investment committed is developing for Pumicestone Passage in south Qld. Likewise there is strong interest for the SA Gulfs and for Oyster Bay in Albany Harbour, WA.

Table 2 summaries activities from an outcome perspective.

Table 2: Summary of Outputs and Outcomes achieved – community

Tasks	Outputs	Outcomes & Comments
Summary information made available and presented on the implications of climate change, especially from an adaptation perspective	Multiple interactions and discussions / presentations. Covered all States, various groups – fishing, natural resource management, community	Knowledge awareness achieved. Nevertheless, more can always be done to foster understanding of the various issues facing fishing, professional, recreational and indigenous, the need to incorporate climate and foster repair and resilience of the productivity systems. Port visits are underway and are resourced through FRDC 2011/039
Marine Report Card	Not achieved – limited FRDC resources + shifting priorities	Climate issues will be incorporated within FRDC investments rather than a specific focus
Short articles for newsletters	Completed	Knowledge awareness achieved and positive feedback – therefore presume well received.
Other Activities not listed in contract	Multiple interactions and discussions / presentations.	The most notable outcome is probably the growing momentum to re-create shellfish reefs across southern Australia as part of habitat repair and resilience to water quality shocks from extreme events.

Target Audience 3 – Science community

Outputs Nominated

Outputs nominated at project inception were:

3.1 2 Science papers co-authored with key scientists:

- Paper 1 – nominally titled "Revitalising Australia's Estuaries – what benefits at what cost?' – co-authors include Marcus Sheaves, Justin Brookes, Paul Boon and Craig Copeland
- Paper 2 – nominally titled "Paradigm Shifts in Sustainable Fisheries Management" – co-authors include Alistair Hobday and Gretta Pecl

3.2 Summary program report on the entire Climate Adaptation program – in progress and with input from all Principle Investigators.

3.3 Finalisation of all remaining science contracts to Final Report stage together with additional R&D projects on habitat as already directed by FRDC. Projects to be completed included:

- 2010/506 – temperate Reefs [PI - Neville Barrett]
- 2010/535 – WA fisheries [PI – Nick Caputi]
- 2010/542 – Blueprint for coastal communities [PI – Stewart Frusher]
- 2010/565 – Northern Australia [PI – David Welch]
- 2010/039 – South Eastern Australia [PI – Gretta Pecl]
- 2011/040 – Estuarine and nearshore [PI – Marcus Sheaves]
- 2011/503 – Community Knowledge [PI – Jenny Shaw]
- 2010/023 – Atlantis [PI – Beth Fulton]
- 2013/029 – Comparative Threats [PI – Bob Kearney]

Summary of Outputs delivered

- Approval and publication of the science paper titled *Repairing Australia's estuaries for improved fisheries production – what benefits at what cost?* – Australian Journal of Marine and Freshwater Research 2014; Co-authors were Paul Boon, Justin Brookes and Marcus Sheaves [Creighton, C et al 2014b)];
- Draft final science paper titled *Adapting management of marine environments to a changing climate – a checklist to guide reform and assess progress*; Co-authors are: Alistair Hobday, Michael Lockwood and Gretta Pecl [Creighton, C et al 2014c)];
- Use of summary Program report titled *Marine Australia – Directions for management and further research* [Creighton, C 2014a)] as a basis for discussion on further research, the need to focus on adaptation rather than problem definition and to demonstrate to the science community that many of the adaptations required for a changing climate can be achieved through other broad agendas such as improving marine management efficiencies and effectiveness;
- Progressive review, suggestions for improvement and then finalisation of all project Final Reports ready for uploading on the revised Climate section of the FRDC website;
- Progressive review and approval of science papers produced by Principal Investigators and their teams, also then made available via links from the FRDC website;
- Work collaboratively with key science providers to meet, then prepare a Briefing Paper on Estuary Repair R&D priorities and engagement with key Senators in an attempt to secure funds, initially under the then proposals for a new Cooperative Research Centre round and later under the proposed National Environmental Science Program;
- Input to Marine Strategy process being coordinated through the National Marine Science Committee with the input including;
  - ensuring adaptation to a changing climate was included in the Climate white paper
  - leading, preparing and gaining collaborative support for a white paper on Estuary Repair [Creighton, C et al 2014d)]
  - ensuring both climate adaptation and resilience through habitat repair was part of several other white papers

- attending the 2 day forum and ensuring climate adaptation and resilience through habitat repair was included in the various relevant discussions [Canberra, 25 and 26 November 2014];

- Attending and interacting with the National Estuary Network as the Australia-wide team deliberates on the next phases of the Network's activities
- Participating in the joint Conference of the Australian Societies of Aquatic Ecology and Fisheries Biology and presenting two papers, one on climate adaptation and the other on resilience through repair;
- Providing advice to officers in various states as they prepare local business cases and action plans for estuary repair investment – especially NSW, Vic, WA and SA;
- Presenting to several SA and WA forums, including SARDI, Murdoch University Centre for Fish and Fisheries and the Western Australia Marine Science Institute;

Reflections on outputs delivered and their role in fostering engagement and improved knowledge

From a climate change perspective, some cynics worldwide within and outside the science community have suggested that climate change was just the latest funding bandwagon for science [e.g. Prof Bjorn Lomberg, as regularly cited in *The Australian*]. Nevertheless the quality of the science undertaken in the Climate Change Adaptation program, as gauged by the number of resulting published papers was exceptionally high and relevant. This is a strong indication of the willingness of Australian science to seek answers, to think through and recommend adaptation options and to place climate science within the bigger context of smarter management systems for Australia's marine biodiversity and fisheries.

Likewise, the Australian scientific community is interested in the productivity and resilience aspects of habitat repair. A strong indication of interest is that the National Estuary Network, set up in 2002 as part of the National Land and Water Resources Audit [NLWRA, 2002] remains an active, all States and Australian agencies group, sharing knowledge across Australia and meeting regularly without supplementary funding. The now building interest in restoration ecology, in the scientific and economic aspects of modifying and sometimes changing coastal land use and in shellfish reefs further demonstrates scientific interest in Australia's coastal zone and its most appropriate use and management for multiple benefits.

The challenge remains for science to focus more on the solution rather than the problem. This is particularly evident in a cultural environment where the media and various campaigns choose to focus on the problem, the sensationalist or negative aspects of any issue.

Overall, this component of the contract was delivered most comprehensively, with an audience that was most receptive to the tasks and presentations / discussions / opportunities for further engagement and action.

To conclude the entire Climate Change Adaptation Program, a subgroup of the Principle Investigators was convened to reflect on progress and the substantive process issues for the conduct of science and its application to policy using climate change as the test case. The group distilled from the portfolio of research findings a suite of key elements required of policy and management to adequately adapt and respond to a changing climate. These elements were then structured into three phases and will be presented in a science paper as a checklist for guiding reform and assessing progress towards a climate ready marine future [Creighton, C et al in prep; final draft one of the attachments to this Report)].

Management of marine resources for conservation and sustainable harvest is regarded as more challenging than ever. A range of anthropogenic activities has triggered environmental changes that greatly exceed the natural background fluctuations (Rockstrom et al. 2009, Steffen et al. 2011). Most pervasive is a changing climate resulting in altered physical conditions in many marine regions around the world (Doney et al. 2012; Hobday and Pecl 2014). Concomitant changes in distribution, abundance, physiology and phenology are already evident for many marine species (Doney et al. 2012, Poloczanska et al. 2013). Nowhere is this change more evident than at the coasts where the documented and predicted increases in temperature, acidity, UV radiation, nutrient concentrations, fishing pressure, coastal constructions, frequency and duration of hypoxic events are thoroughly documented (e.g. Hoegh-Guldberg et al. 2007, IPCC 2013). The speed of change in average environmental conditions and the increased frequency of extreme events (heat waves, hypoxia) may exceed the potential of marine organisms for tolerance or adaptation (IPCC 2014, Koehn et al. 2011). Moreover, global change is multifactorial and the compound action of several stressors often is synergistic (Brown et al. 2013). Global change will also lead to altered responses, economic opportunities and conservation priorities, all of which will require revised policy frameworks and management approaches operating at faster time scales than these institutions tend to operate.

Systems thinking demonstrates that climate and its impacts are but one of many issues that need to collectively be the input to policy and to management decisions. Indeed marine management by virtue of being multi-objective and needing to meet diverse and sometimes competing user needs is best served by a multi-component approach that incorporates climate as one of many issues to be accommodated. Responses to address the challenges of climate change will range from those that are minor or incremental through to those that involve more radical shifts in resource management and utilisation (Stafford-Smith et al. 2011; Park et al. 2012; Wise et al. 2014). To acknowledge this, it is suggested that there are three interlinked phases of the adaptation process.

Historically, management of marine biodiversity and resources has not necessarily or typically taken a systems view. Thus, there is a need to ensure that policy; management and institutional structures are better aligned so that there is a solid platform on which to develop adaptation responses (Wise et al. 2014; Frusher et al. 2014). This first necessary phase is best termed '***preconditioning***' [Creighton, C et al in prep]. On reflection, some of the difficulties experienced in delivering that part of this sub-project to senior policy makers and managers mirror these issues.

Once policy and management structures are aligned, '***future proofing***' of systems can include the knowledge assimilation and building of conceptual understanding required to begin operational processes and actions. Elements under this category highlight the need for integrated systems thinking and approaches, based on an interdisciplinary and socio-ecological systems view. While all presentations and discussions undertaken in this project attempted to present an integrated or systems view, the receptivity of the various audiences to this approach varied.

Lastly, to facilitate the sustainable use and conservation of living marine resources into a vastly different future, both '***transformation and opportunity***' need to be considered. The types of issues to be dealt with here include:

- Changes brought about by a changing climate must be assessed for beneficial opportunities;
- In responding to increased climate variability and change, a transition towards flexible total stock management systems is essential;
- Policy and management must take advantage of the key role marine ecosystems can have in carbon sequestration;
- Carbon sequestration in marine systems is best done as part of a multi-objective approach.

Australia's policy and management systems are still developing to meet these challenges.

The activities and outcomes of this phase of the contract are presented in summary form in Table 3.

Table 3: Summary of Outputs and Outcomes achieved – science community

Tasks	Outputs	Outcomes & Comments
Science papers co-authored with key scientists	1 paper published & 2nd papers well in progress	Sound foundation for further science with published paper already widely cited
Summary program report on the entire Climate Adaptation program	Completed and approved by FRDC	Sound foundation for further science + demonstrates the benefits of a program approach to science commissioning, management and knowledge exchange.
Finalisation of all remaining science contracts to Final Report stage together with additional R&D projects on habitat as already directed by FRDC	Completed	The large number of science papers the program has generated possibly best gauges the quality of the science.
Other activities not listed in contract	Multiple interactions and discussions / presentations / meetings.	A series of R&D initiatives are either proposed or underway, especially on productivity resilience / repair of habitat. Rapid shift in Australian Government policy re climate change is probably precluding major interest in seeking funding for the various outstanding climate change related knowledge needs

Conclusions

Objectives and Outcomes sought

The project objectives and proposed outcomes are as follows:-

Objective 1: Smarter fisheries management
– provide the information to foster an improved understanding of the implications of climate change on fisheries stocks, fishing effort and marine biodiversity, thereby providing input into Australian and state based fisheries management and policy.

Outcome sought: Through FRDC briefings, Australian Fisheries Management Forum member awareness and action towards incorporating the implications of a changing climate into improved, next generation fisheries management arrangements.

Objective 2: Repaired more productive and resilient inshore habitat
- building on the climate adaptation imperatives of resilience and carbon sequestration opportunities of inshore habitat together with the opportunities of Direct Action, foster works and activities that will ensure increased inshore productivity for professional, recreational and indigenous fishers

Outcome sought: Ideally, *Direct Action* and related Australian Government natural resources management policy agendas including an estuarine / nearshore marine component covering fresh to brackish wetlands, mangrove, saltmarsh and seagrass repair, recognising the multiple benefits as well as carbon sequestration that these environments provide and investing in repair accordingly

Objective 3: Increased investment in knowledge generation
– articulate the benefits of resourcing R&D for the key knowledge gaps across climate adaptation, carbon sequestration and inshore fisheries habitat and seek for FRDC co-investment partnership arrangements with key Australian Government agencies

Outcome sought: Increased knowledge on the opportunities for smart climate adaptation and habitat management as part of enhancing Australia's marine biodiversity, fisheries productivity and sustainable economic yield

Objective 4: Maximise science quality, outputs and dissemination of existing investments
– review and evaluate to ensure a high standard of all draft milestone and draft final reports, all remaining unfinished projects.

Outcome sought: High standard science outputs readily available to all users in summary and full detail forms and via both electronic and print media

Outcomes for Objectives 3 and 4 have been well met. These two sets of objectives and outcomes are to a large degree within the control of FRDC and its agents, especially through this sub-project and its companion activities.

Outcomes for Objective 1 are a work in progress. As an example of the complexity of the policy and management change processes, consider the need, with a changing climate and spatially changing stocks to transition to whole-of-stock management. Use snapper [*Chrysophrys auratus*] as an example.

Snapper is a large, long-lived, demersal finfish species that is abundant throughout the coastal waters of Australasia. The species has a broad Australian distribution that includes the coastal waters of the southern two thirds of the continent, including southwards from the mid-coast of Western Australia, the southern continental coastline and north coast of Tasmania, and the east coast up as far as north Queensland [Kailola et al 1993; Jackson 2007]. Throughout this distribution, snapper occupy a diversity of coastal habitats including bays, inlets, gulfs and open marine waters to the edge of the continental shelf to a depth of at least 200 m. Consequently, across the different places, the various life history stages of snapper are exposed to a range of environmental conditions.

The south-eastern region of Australia supports three apparently different stocks [Pecl et al 2014]. The Eastern Stock extends from Wilson's Promontory in eastern Victoria up the coast of New South Wales and Queensland. The Western Victorian stock is thought to extend from Wilson's Promontory westward into South Australian waters adjacent to the mouth of the Murray River. This stock includes the important Port Phillip Bay fishery. The South Australian stock extends westwards from the Murray mouth into Western Australian waters and includes the populations of Spencer Gulf and Gulf St. Vincent.

Recruitment of 0+ snapper into nursery areas in South Australia and Victoria demonstrates significant inter-annual variation, which ultimately drives the population dynamics and variation in fishable biomass and fishery productivity (Fowler et al 2005). This variability is thought to relate to inter-annual variation in survivorship of snapper larvae [Pecl et al 2014]. The populations of snapper in NSW and Qld do not demonstrate such high recruitment variability, which may be linked to the broad distribution of spawning in oceanic coastal waters, and the fact that juvenile recruitment occurs in a large number of different inshore bays and estuaries.

Significant recreational and commercial fisheries for snapper are found in each of SA, Vic, NSW, WA and Qld. These various State-based fisheries are managed independently of each other, which is problematic for assessment and management when stocks straddle jurisdictional boundaries (i.e. the Eastern stock straddles QLD, NSW and Vic, and the Victorian western stock straddles Vic and SA).

If there is ever to be stock-based management then the following complexities will need to be addressed:

- sound stock prediction tools and preferably well demonstrated outputs, probably over 5+ years as an evidence base for management options
- agreement by fishers, commercial and recreational in all the relevant jurisdictions to transition to stock-by-stock management
- the development of stock-by-stock management options
- agreement among all fishers and fisheries management in the relevant jurisdictions to a preferred management option, including any changes to resource allocation / sharing
- agreement between the relevant jurisdictions for some form of joint management mechanisms - possibly including a lead jurisdiction, transfer of management resources and so on
- some form of agreed regulations across jurisdictions and so on

This sub-project, temporally constrained as it was, succeeded in alerting fisheries managers and policy maker to the policy and management implications of a change climate.

Outcomes for Objective 2 were also extremely optimistic given that "blue carbon" is yet to be fully recognised under global carbon accounting schemes, let alone the excessive political scrutiny of all matters regarding climate policy in Australia making it extremely difficult to include innovative concepts in *Direct Action*. Nevertheless substantial progress has been made towards developing an ethos of repairing resilience. Individual project proposals identified in *Revitalising Australia's Estuaries* [Creighton, C 2013] have been resourced in WA [e.g. Vasse – Wonnerup], SA [e.g. fishway connectivity for the islands and barrages, Lower Murray], Vic [e.g. shellfish reef pilot, Port Phillip Bay], NSW [e.g. Everlasting Swamp acquisition] and Qld [e.g. Great Barrier Reef systems repair]. For the Great Barrier Reef the Long Term Sustainability Plan [Australian Government, 2014] has endorsed the need to repair coastal ecosystems and has as one of its targets:

EHT1 – Condition and resilience indicators for coral reefs, seagrass, islands, estuaries, shoals and inter-reefal shelf habitats are on a trajectory towards achieving at least good condition at regional and reef-wide scales.

Certainly, this is major progress in recognition of the Reef as a system and that of all the component ecosystems, estuaries and wetlands are the most degraded.

Implications

This multi-investor science program has delivered substantial improvements in our knowledge on estuarine, nearshore and marine systems, their biota and use and how Australia might best adapt its policy and management to respond to a changing climate. On that basis alone, the program has proved to be an excellent investment.

Capitalizing on the knowledge learnt via extension and interaction with policy makers, managers, fishers and the broad community is ongoing, but nevertheless has proved difficult in a rapidly changing political / policy climate and as resources for science diminish.

Most importantly, based on the findings of the projects and the recognition that an integrated approach is the most cost-effective response, many of the discussions centered on how to factor in climate, its variability and change into the broader more generic area of marine systems policy and management.

This program and its investments in knowledge transfer will have a successful legacy as climate is included as an attribute being considered when determining marine policy and management. Most R,D&E invested in by FRDC that incorporate the issues of climate will be focused on including climate as an integral part of the continuous challenge to provide the evidence to improve Australia's marine policy and management. Certainly there may be occasional climate-specific investments.

Nevertheless, from an adoption perspective the challenge remains to include the implications of climate, climate change and climate adaptation within the broader perspectives of policy formulation and management of Australia's marine biodiversity and fisheries.

Recommendations

The conclusion of the Climate Change Adaptation Program provides an opportunity to reflect on the design and conduct of a major research program. The construction and management of a program is crucial to the successful delivery of outputs and outcomes, creating emergent value over and above what can be achieved from a range of individual projects.

This following are recommendations arising from this opportune reflection:

Inception

- seek multi-partners / investors across the policy and management community, the end users;
- develop agreement on the key knowledge needs, the timing for delivery of these and how they might best intersect with the policy and management environments;
- establish a broad budget allocation by % to science enquiry, science management, project extension, program knowledge transfer and ongoing interaction with policy and management;

Program Design

- build a conceptual plan from the knowledge needs perspective and out of this conceptual plan will fall most of the specific science projects
- commission much of the science through short form expressions of interest
- ensure additional resources are available for innovative responses to the knowledge needs
- reserve some of the resources for knowledge needs and issues not foreseen at program inception
- review and select science teams for each of the component projects

Program and Project Management

- for all projects ensure strong links to data already available and with the research adding to this data system so that all data is current and readily available and can be built upon by other researchers;

- specify a common base of credible modeled projections for any time / user dependent analysis;
- ensure validation of any projections through the application of monitoring to build a qualitative understanding of change and impacts;
- selectively use scenarios to develop options of policy intervention and management that optimise various outputs;
- foster among the science teams rigor in the development of recommendations for management, policy and monitoring based on the above;
- encourage all science teams to frame their recommendations from two perspectives – the overall outcomes sought and the achievability of the recommendations based on the existing management structures and their capability to implement the recommendations;
- require all projects as part of their contracts to specify data sets, the legacy issues of housing the data sets derived from their work, the preparation of science papers and the dissemination of findings to key users as their projects proceed; and
- at annual intervals encourage strong interaction and discussion between science teams across the program, including with the end users.

Fostering Uptake of Program Findings

- as the program proceeds cross-calibrate with those knowledge needs specified at program inception
- wherever possible foster parallel policy formulation and management improvements to proceed hand in hand with science enquiry
- recognise that multiple communication tools are essential for the various end users; and
- ensure resources are available to continue the conversations with policy makers and managers for at least 18 months after the program's science is complete.

Project materials developed

This sub-project focused on advocacy, engagement and information dissemination. Therefore there were multiple products developed across the three key audiences. A selection of these is listed as follows and has been submitted in electronic form to accompany this final report.

Managers and policy makers

- Australian Fisheries Management Forum presentation [PowerPoint]
- Submissions to Emissions Reduction Fund
  - Terms of reference
  - Green Paper
  - White Paper
- FRAB R&D Investment Opportunities [PowerPoint]
- Submission - Reef Trust and application Australia-wide
- National Environmental Science Program – *Repairing estuary and inshore productivity* [Briefing Paper and PowerPoint]

Fishers and community

- Adaptation case studies [PowerPoint]
- Fish March 2014 – *Habitat: a high yielding investment*
- Fish June 2013 – *Reconnect to revitalise fisheries*
- Natural resource management and coastal ecosystems [PowerPoint]
- Fact Sheet – *Adapting to a changing climate* [with 6 accompanying issue-specific Fact Sheets prepared for key projects through working with and supporting Principal Investigators – Atlantis and SE project]
- Paradigm shifts [PowerPoint]
- Recreational Fishing Group Multi-state template [PowerPoint]
- VRecFish Newsletter - featuring habitat
- VRecFish presentation -featuring shellfish reefs [PowerPoint]

Science community

- Journal of Marine and Freshwater Research 2015– *Repairing Australia's estuaries for improved fisheries production – what benefits at what cost?* Creighton, Boon, Brookes and Sheaves.
- Ecosystems – submitted – *Adapting management of marine environments to a changing climate – a checklist to guide reform and assess progress* Creighton, Hobday, Lockwood and Pecl
- Australian Society of Fisheries Biology *Revitalising Australia's Estuaries* [Abstract and PowerPoint]
- Australian Society of Fisheries Biology *Rethinking fisheries management – responding to a changing climate, habitat loss and community pressures* [Abstract and PowerPoint]
- National Marine Science Symposium - *R&D Priorities – Australia's estuaries, embayments and nearshore marine environments* Colin Creighton, Paul I. Boon, Justin D. Brookes, Marcus Sheaves, Patricia von Baumgarten , Fiona Valesini , Dr Frederieke Kroon and Dr Greg Ferguson
- National Estuary Network *Revitalising Australia's Estuaries - - multiple benefits if we can meet the challenges of turning the tide on past mistakes* [PowerPoint]

Appendices

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Creighton C 2014f) *Rethinking fisheries management – responding to a changing climate, habitat loss and community pressures* Conference Paper Australian Society of Fisheries Biology, Darwin

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Project materials developed

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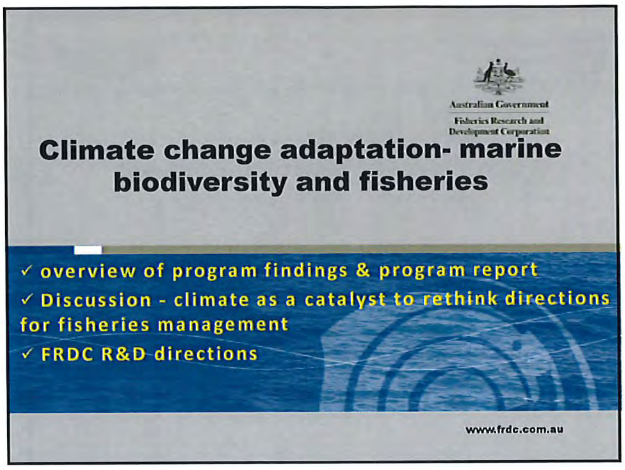
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Fisheries Research and Development Corporation
Climate change adaptation- marine biodiversity and fisheries
✓ overview of program findings & program report
✓ Discussion - climate as a catalyst to rethink directions for fisheries management
✓ FRDC R&D directions
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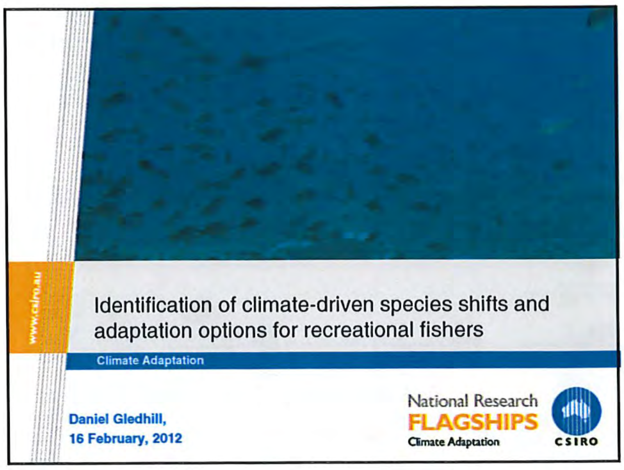
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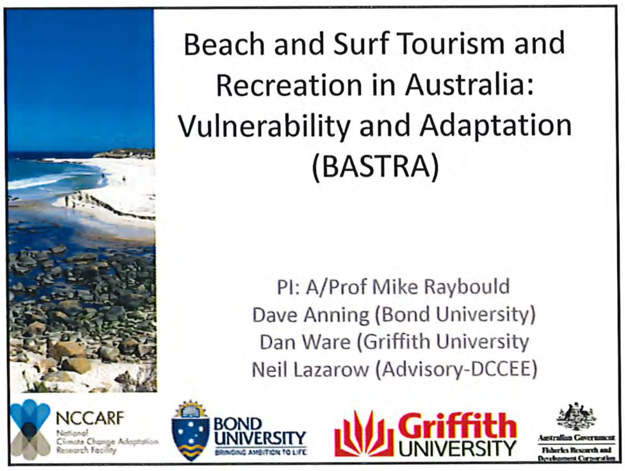
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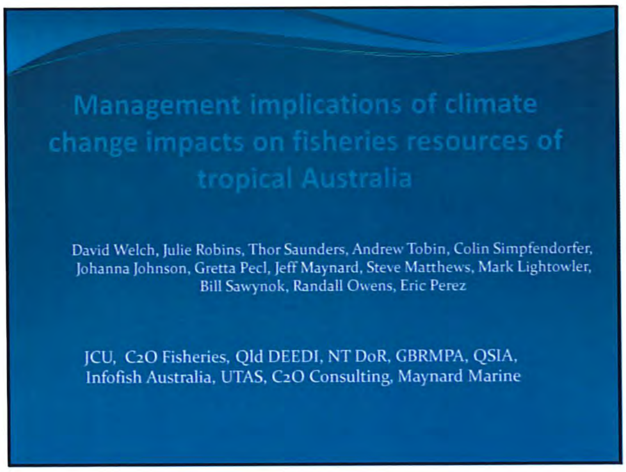
PI: A/Prof Mike Raybould
Dave Anning (Bond University)
Dan Ware (Griffith University
Neil Lazarow (Advisory-DCCEE)
NCCARF
National Climate Change Adaptation Research Facility
BOND UNIVERSITY
Griffith UNIVERSITY
Australian Government
Fisheries Research and Development Corporation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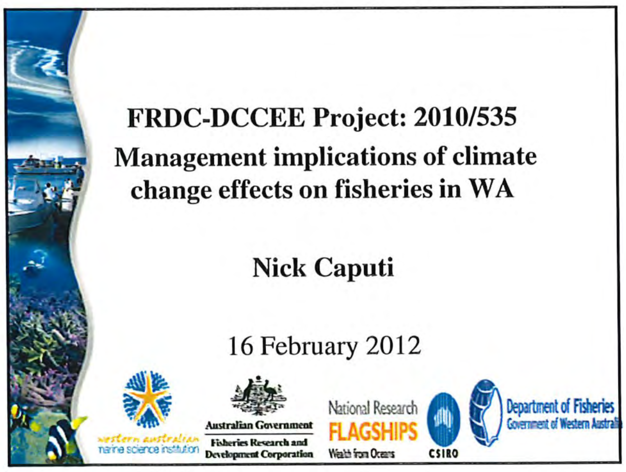
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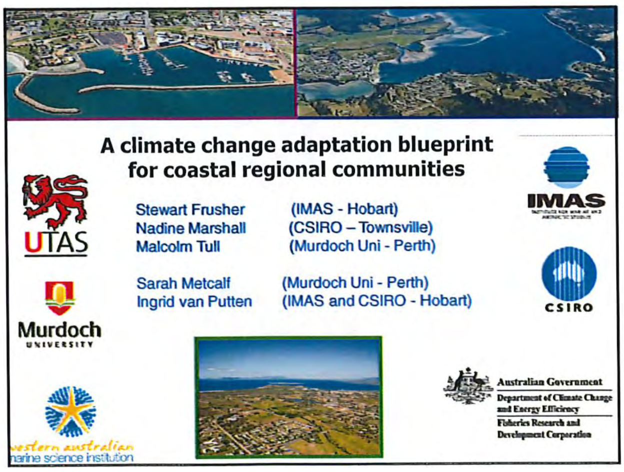
A climate change adaptation blueprint for coastal regional communities
Stewart Frusher (IMAS - Hobart)
Nadine Marshall (CSIRO – Townsville)
Malcolm Tull (Murdoch Uni - Perth)
Sarah Metcalf (Murdoch Uni - Perth)
Ingrid van Putten (IMAS and CSIRO - Hobart)
UTAS
Murdoch UNIVERSITY
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western australian marine science institution
Australian Government
Department of Climate Change and Energy Efficiency
Fisheries Research and Development Corporation

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Preparing fisheries for climate change: identifying adaptation options for four key fisheries in SE Australia

Team: Gretta Pecl & Tim Ward (co-PI's)
Dallas D'Silva, Caleb Gardner, Philip Gibbs, Andrew Goulstone, Alistair Hobday, Greg Jenkins, Stephen Mayfield & many others

IMAS - in partnership with the Tasmanian State Government

Aquaculture Genetics James Cook University

Vulnerability of barramundi and related industries to climate change

Dean Jerry, Carolyn Smith-Keune, Guy Carton, Jeremy vanderWal, Igor Pirozzi, Kate Hutson and John Russell (QDEEDI)

James Cook University
Townsville, QLD
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Changing Currents in Marine Biodiversity Governance and Management: Responding to Climate Change

Michael Lockwood[a]
Julie Davidson[a]
Marc Hockings[b]
Marcus Haward[c]
Lorne Kriwoken[a]

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[b]Geography, Planning & Env. Management, University of Queensland
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Assessing Alternative Adaptive Management Strategies for Estuarine and Coastal Ecosystems

Marcus Sheaves JCU
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Jeremy Hindell DSE
Marie Savina-Rolland CSIRO
Pat Dale GU
Nina McLean JCU

Effects of climate change on coral trout (*Plectropomus leopardus*)

Morgan Pratchett, Philip Munday, Vanessa Messmer
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Richard Knuckey, Adam Reynolds
QDEEDI Northern Fisheries Centre, Cairns

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Neville Barrett, Graham Edgar, Neil Holbrook and others

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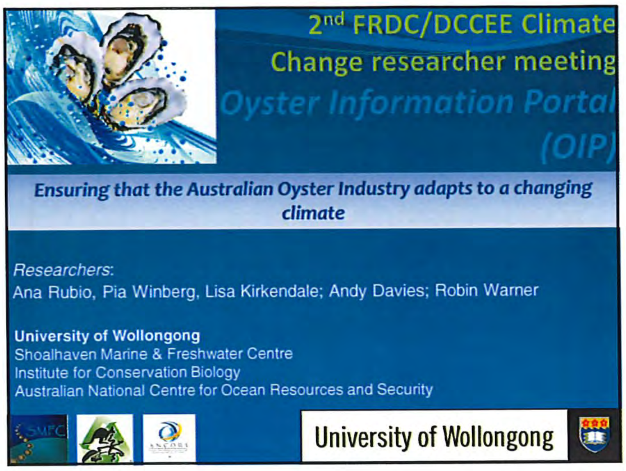
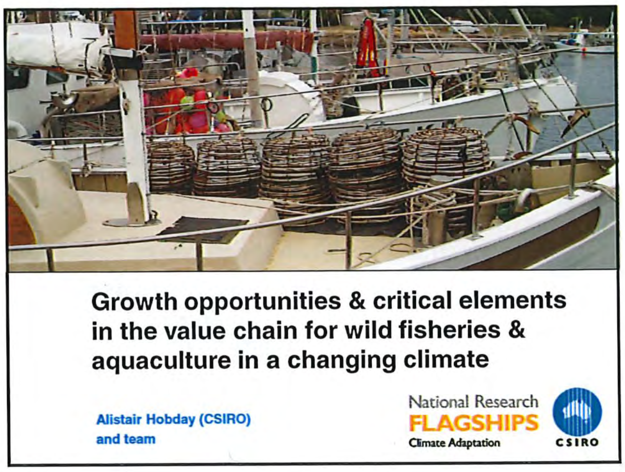
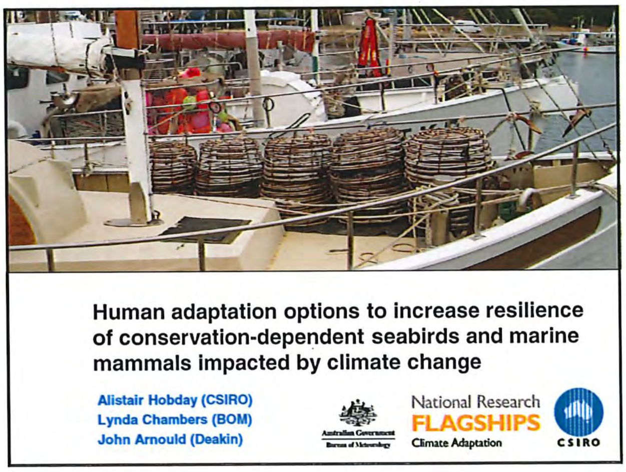

2nd FRDC/DCCEE Climate Change researcher meeting
Oyster Information Portal (OIP)
Ensuring that the Australian Oyster Industry adapts to a changing climate
Researchers:
Ana Rubio, Pia Winberg, Lisa Kirkendale; Andy Davies; Robin Warner
University of Wollongong
Shoalhaven Marine & Freshwater Centre
Institute for Conservation Biology
Australian National Centre for Ocean Resources and Security
University of Wollongong


Growth opportunities & critical elements in the value chain for wild fisheries & aquaculture in a changing climate
Alistair Hobday (CSIRO)
and team
National Research
FLAGSHIPS
Climate Adaptation
CSIRO


Human adaptation options to increase resilience of conservation-dependent seabirds and marine mammals impacted by climate change
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Lynda Chambers (BOM)
John Arnould (Deakin)
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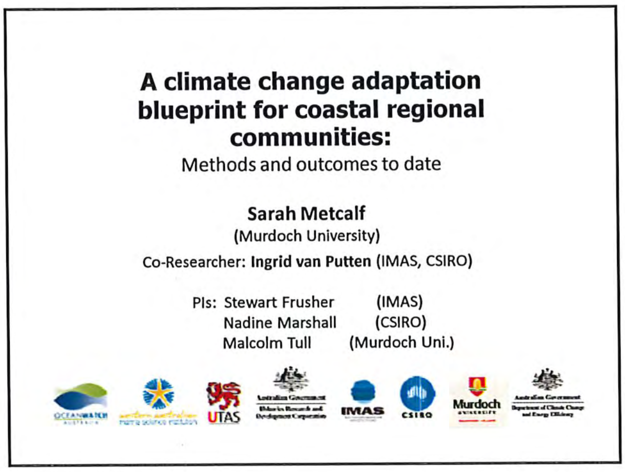
A climate change adaptation blueprint for coastal regional communities:
Methods and outcomes to date
Sarah Metcalf
(Murdoch University)
Co-Researcher: Ingrid van Putten (IMAS, CSIRO)
PIs: Stewart Frusher (IMAS)
Nadine Marshall (CSIRO)
Malcolm Tull (Murdoch Uni.)
UTAS
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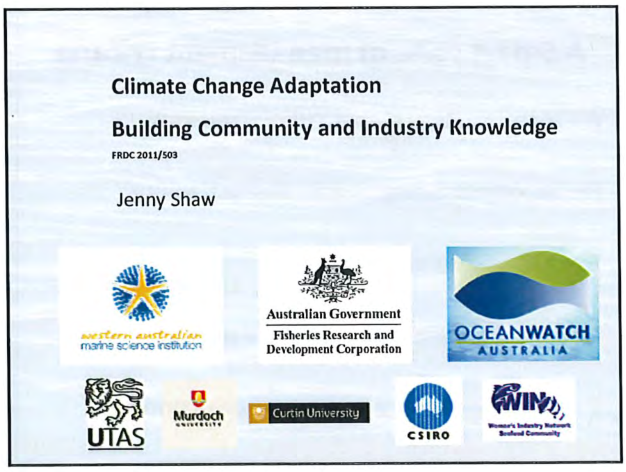
Murdoch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Building Community and Industry Knowledge
FRDC 2011/503
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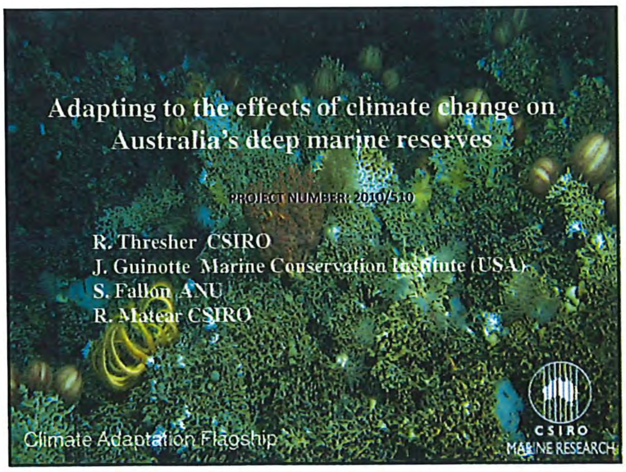
Australian Government
Fisheries Research and Development Corporation
OCEANWATCH AUSTRALIA
UTAS
Murdoch
Curtin University
CSIRO
WIN


Adapting to the effects of climate change on Australia's deep marine reserves
PROJECT NUMBER: 2010/510
R. Thresher CSIRO
J. Guinotte Marine Conservation Institute (USA)
S. Fallon ANU
R. Matear CSIRO
Climate Adaptation Flagship
CSIRO
MARINE RESEARCH

FRDC-DCCEE: preparing fisheries for climate change: identifying adaptation options for four key fisheries in South Eastern Australia, 2011/039

PRINCIPAL INVESTIGATORS: **Gretta Pecl and Tim Ward**

Final report due January 10th **2014**

Overview of Program Report
[in your agenda papers]

C1 – introduction, close to $10M R&D effort

C2 – key findings across all projects

C3 – a climate checklist

C4 – priority knowledge needs

Appendix – executive summaries of all projects

Summary Fact Sheets
[in your agenda papers]

1 – Overview – directions for marine management

2, 3, 4 & 5 – South East key species
* Abalone * Southern Rock Lobster
* Blue Grenadier * Snapper

6 – Projections for changing marine biomass

7,8,9,10,11 & 12 – Supply chains & changing climate
* Southern Rock Lobster * Wild Banana Prawn
* Tropical Rock Lobster * Commonwealth Trawl
* Sydney Rock Oyster * Prawn Aquaculture

Rethinking marine biodiversity &fisheries management

- responding to a changing climate, habitat loss & community pressures

Key findings - FRDC – DCCEE Climate Adaptation – Marine Biodiversity & Fisheries R&D Program

Imperatives for marine biodiversity & fisheries management

Key descriptors for successful management -
- dynamic, changing, flexible, adaptive, resilient, integrative and responsive

Status -
- reactive policy, value laden, limited evidence, inherently refractory decision making, simple [and often incorrect] messages, inadequate understanding

A 5-part suite of management criteria

A – incorporating climate in our thinking

B – accommodating shocks and variability

C – responding proactively

D – re-building productivity and profitability

E – contributing to a smart carbon economy

A suite of management criteria
[A -incorporating climate in our thinking]

1. **Climate adaptation** – a part of much larger social and economic adaptation [e.g. changing input costs / technology / commodity prices & markets]
2. **Climate** – part of integrative, more multi-objective policy & management [within sustainable economic yield & conservation policies]
3. **Management approaches** – developing policies that match in coverage [spatially and temporally] what we seek to manage [more holistic / regional approaches e.g. snapper; eastern and southern rock lobster; abalone]

A suite of management criteria
[B - accommodating shocks and variability]

4. **Minimising the impact of extreme events** – an imperative for fostering resilient, healthy ecosystems [e.g. cyclone impacts on coral trout fishery; western rock & abalone – Leewin current;]
5. **Catchment management** – essential for fisheries outcomes [e.g. fish kills with floods; Shark Bay prawn and scallop]
6. **Responding to variability** – towards flexible total stock management [e.g. barramundi @ 3 years; prawns annually;]

A suite of management criteria
[C - responding proactively]

7. **Responding to changing interactions** – including climate influences in any assessments [eddies and fish concentrations, Eastern Australian Current; recreational fishing target effort]
8. **Responding to threatening processes** – to ensure ecosystem integrity [e.g. static marine park boundaries; water quality and habitat loss]
9. **Responding to non-static conditions** – policy, procedures and regulations must be as flexible as the variability of the stocks and ecosystems we seek to manage [e.g. Eastern Blue Groper; sea urchin – kelp - Southern Rock Lobster interactions;]

A suite of management criteria
[D - re-building productivity and profitability]

10. **Repairing for increased resilience** – a priority for investment [especially inshore habitat]
11. **Protecting key species** – site and species specific investment will be essential [e.g. seabirds marine mammals]
12. **Changing climate** – a profitability opportunity [e.g. Eastern Rock Lobster; Barramundi aquaculture; concentrations on eddies; mussel and oyster reefs as 3D natural habitat]

Mitigation & Energy efficiency
[E - contributing to a smart carbon economy]

13. **Marine ecosystems** – a key role in carbon sequestration (and Australia's regional development!) [mangroves, seagrasses, fresh to brackish wetlands and salt marshes are the highest per hectare carbon sequesters]
14. **Smarter fuel & energy use** – essential for profitability [e.g. fuel management, gear technology]

Australian Government
Fisheries Research and Development Corporation

FRDC R&D directions

- ✓ incorporate climate as an integral part of marine biodiversity and fisheries R&D
- ✓ only invest in very high priority climate-specific R&D
- ✓ encourage closer interaction & integration between marine biodiversity and fisheries R&D
- ✓ encourage essential R&D by others e.g. improved marine forecasts linked to IMOS data sets.

www.frdc.com.au

Australian Government

COVER SHEET FOR SUBMISSIONS

EMISSIONS REDUCTION FUND

This completed form must be included with your submission. If completing by hand, please ensure your writing is clear and legible.

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Organisation (if applicable)	Self on behalf of Australia's coastal ecosystems and all the benefits they provide the Australian community – fish, water quality, biodiversity, flood protection, landscape and about 39% of Australia's carbon sequestration
Title	Mr
First name	Colin
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Postal address	Lex Creek Nature Refuge PO Box 690 DALRYMPLE HEIGHTS QLD 4757
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Return BOTH the cover sheet and the comments sheet by email (preferred option) or post to the addresses below.

Email: emissions-reduction-submissions@environment.gov.au

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Department of the Environment
GPO Box 787
CANBERRA, ACT 2601

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Australian Government

SUBMISSION TEMPLATE

EMISSIONS REDUCTION FUND

Overview

This submission template should be used to provide comments on the design of the Emissions Reduction Fund.

Contact Details

Name of Organisation:	Self on behalf of Australia's coastal ecosystems and all the benefits they provide the Australian community – fish, water quality, biodiversity, flood protection, landscape and about 39% of Australia's carbon sequestration
Name of Author:	**Colin Creighton**
Date:	**4 November 2013**

Submission responses

Issue - the likely sources of low cost, large scale abatement to come forward under the Emissions Reduction Fund;

Assumption 1 - The lowest cost schemes must surely be those that make a profit far greater than the level of Government [public] investment and then do not require recurrent investment.

Assumption 2 - Given the actual $ value of carbon is somewhat unpredictable, the lowest cost schemes will also be those that while sequestering maximum amounts of carbon, also yield substantial $ profits to the Australian economy.

So to the facts:

1 - Australia's coastal wetlands sequester about 39% of Australia's carbon [see Lawrence et al and accompanying references, FRDC website – and can be emailed as a PDF if required.] Wetlands here refer to fresh to brackish coastal wetlands + salt marshes + mangroves + seagrasses.

2 – Australia's coastal wetlands such as Tuckean, Broadwater, Everlasting to name just 3 in Richmond and Clarence, NSW are currently major emitters of methane.....so repairing these wetlands to once again being carbon sequesters is a double win on the carbon front without detailing water quality improvement, flood protection and fisheries productivity / biodiversity.

3 – Indeed, Australia's coastal wetlands are more than carbon – they are the basis for fisheries productivity, coastal biodiversity, water quality, flood buffers and so on. Its win-win-win–win-win for any investment in coastal ecosystems

4 – The Australia wide Business case – ***Revitalising Australia's Estuaries*** identifies that an investment of $350M would be well and truly returned to the Australian economy just in selected fishery increased productivity in less than 5 years. [Business case is on the FRDC website and can be emailed as a PDF if required]

5 – Actual carbon sequestered cannot of course be precisely quantified until the full details of the investment and works are specified – suffice it to say investment in ***Revitalising Australia's Estuaries*** per hectare it will provide the greatest level of carbon sequestered of any investment.

So please a plea from the 80% of Australians that live and recreate and enjoy our coastal ecosystems....this time do not forget about the wet bits! Our coastal ecosystems help define our Australian lifestyle. Equally importantly they are the highest per hectare sequesters of carbon of any natural system, including rainforests. They are also valued for their other benefits and if repaired will yield return on investment far greater than just the carbon price.

- ***how the Emissions Reduction Fund can facilitate the development of abatement projects, including through expanding the Carbon Farming Initiative and drawing on the National Greenhouse and Energy Reporting Scheme;***

None of these schemes actually include "marine Australia". First step is to make sure our coastal ecosystems are included – fresh to brackish wetlands, saltmarshes, mangroves and seagrasses.

Indeed I would go so far as to suggest the Carbon Farming Initiative was a thinly disguised attempt to "buy" the votes of rural Australia. Any review of the science will soon reveal that soil carbon is important for soil health and should be done for sustainability reasons BUT provides miniscule benefit in terms of carbon sequestration.

Further aspects such as plantation forestry and riparian revegetation were hardly well promoted in the CFI. [As an aside I have well over 10,000 plantation hoop pines, a locally native timber as a plantation forest for high value veneer. I also have probably over 5000 Eucalypts – principally the locally native E grandis along my creek lines – all planted. Yet the CFI was not providing any glimmer of an incentive for me to further my sustainable land management vision.]

My CFI, if I was to design it would concentrate on:

1 – coastal ecosystems

2 – plantation native forestry, especially high value natives

3 – native riparian revegetation.

As to the National Greenhouse Reporting Scheme, many other countries are reporting what is termed "blue carbon". Its time Australia did likewise and reported on the protection and where possible repair of our coastal ecosystems.

the details of auction arrangements to deliver cost effective outcomes;
Auctions are NOT the appropriate vehicle. It is like saying we will have a carbon tax to account for an economic externality to our development called air pollution. That was an abysmal failure in public policy. Externalities such as air pollution cannot be successfully fully mitigated through our current economic system. There has to be public investment for overwhelming public good. **Where we have real opportunities is where public investment can also deliver private as well as public benefits. Repairing our coastal ecosystems is one such example.** Refer to **Revitalising Australia's Estuaries** [see Fisheries Research & Development Corporation website or request from me a PDF] – a total investment of public funds of $350M over 5 years will be more than returned in private benefits of increased seafood productivity for Australian and export consumers in the same time frame.....and benefits of carbon as well and biodiversity etc. As before in the submission – the real public policy innovation Australia requires is where public investment yields both public and private benefits well above the initial level of public investment and preferably sustainable ongoing benefits well into the future. **Revitalising Australia's Estuaries** provides one such opportunity.
the governance arrangements that will support the Emissions Reduction Fund, including the role of key institutions such as the Clean Energy Regulator;
Not close enough to comment. I do know the CFI was excessively bureaucratic. We need agreed but conservative values for carbon sequestered from any particular on farm practice rather than cumbersome and costly site by site monitoring systems. Keep it simple and easily implementable.
• ***the details of the monitoring, verification, compliance and payments arrangements for successful bidders at auction;***
As above – auctions are a nonsense. Be courageous and properly develop public policy and priorities for investment.
transitional issues relating to the existing Carbon Farming Initiative;
Trash it and start again. Key criteria of the new CFI must be: 1 – include coastal ecosystems 2 – include plantation forestry 3 – provide "look up table" style values for various Australian landscapes and listed practices and provide any incentives accordingly [e.g. riparian veg of "xx" trees per linear kilometre in bioregion "ZZ" equals "BB" tonnes of carbon]

4 – maximise opportunities for private and public joint benefits
the design and operation of a mechanism applying to emissions above the business as usual baseline]
Repairing past degradation must be recognised as "above business as usual" as the first criteria. After that it comes back to industry by industry best practices – though my experience in agriculture suggests most of practices that do sequester carbon should be best practice anyway – that is certainly the case with my in-depth practical and scientific experience in dairy, sugar and grains.

Australian Government

COVER SHEET FOR SUBMISSIONS
EMISSIONS REDUCTION FUND GREEN PAPER

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For further information, please call 1800 852 974.

Submission – Emissions Reduction Fund Green Paper

Author: Colin Creighton
Contact: colinmwnrm@bigpond.com and +61 418 225894
Date: 21 February 2014

1. Preamble and context to this submission

This submission is prepared in the following context:

- It recognises, as indeed did the Howard Government, that the Kyoto Protocol was sub-standard in its design.
- It suggests that Australia should go well beyond the constructs and constraints of the Kyoto protocol in its design of an Emissions Reduction Fund
- As just one example of the limited thinking in the Kyoto protocol, Kyoto emphasised the role of "planted trees" – a Euro-centric, conservation orientated perspective. For Australia's landscapes, natural revegetation by fencing and removing stock is far more cost effective and efficient than planting and most importantly will deliver a greater and more sustainable sequestration return than "planting trees".
- This submission therefore deals with another key omission of the Euro-centric, terrestrially and anthropocentrically focused Kyoto Protocol – the role of nearshore coastal and marine systems.
- It seeks to detail a key area of Emissions Reduction that will optimise carbon sequestration as well as delivering multiple other benefits to the Australian community – in short, the concept is known as "blue carbon".
- If those designing the Emissions Reduction Fund are keen to ensure that the Fund delivers comprehensively and in a specifically Australian way to Australia's carbon economy and Australia's future national growth, then please read on.

2. Key Points against the Green Paper's listed policy positions

> *The Emissions Reduction Fund will be designed to achieve lowest-cost emissions reductions as its primary objective.*
>
> *Views are sought on opportunities for large-scale, low-cost emissions reductions, including estimates of potential reductions.*

Response:

Single objective policies are always sub-optimum in their delivery to Australia's multiple needs across our economic growth, social well-being and environmental condition. Therefore I would add the following statement to the first sentence above –

As a secondary objective for the Emissions Reduction Fund, priority amongst lowest-cost emissions will then be allocated to those activities that also deliver to Australia's economic growth, social well-being and environmental improvement.

In the case of "blue carbon", works to re-create functioning coastal wetlands, productive mangrove, salt marsh and seagrass communities will deliver the highest per hectare sequestration opportunities of all Australian landscapes and multiple other benefits – fish, food, regional jobs, coastal extreme event buffering, biodiversity, lifestyle improvement, enhanced water quality and so on.

That is – **BLUE CARBON IS THE LOWEST-COST EMISSIONS REDUCTION OPORTUNITY OF ALL OPPORTUNITIES WITHIN THE BROAD CATEGORY OF LANDSCAPE-TYPE OPPORTUNITIES.**

But it does not stop there. As well as being lowest-cost emissions reduction opportunity of all landscape scale opportunities, these investments will deliver regional jobs, seafood, environmental repair and support the Australian coastal lifestyle forever. **HEALTHY FOOD AND LOCAL JOBS FOREVER.** While these may be secondary benefits from an Emissions Reduction Fund perspective, recognising the demise of many other parts of the Australian employment economy, these outcomes are central to Australia's economic growth and well-being.

As an example of additional benefits to the highest rate of carbon sequestration per hectare of any landscape-based activities, the recently prepared Business Case for Estuary Repair [see url at back of this Submission] focused on the returns in increased fishery productivity. Case studies demonstrating that an Australia-wide investment of $350M would be returned just in fisheries increased productivity in less than 5 years.

Emissions reduction methods will be developed to calculate genuine and additional emissions reductions from new actions that are not mandatory and have not been paid for under another programme.

Views are sought on how best to:

- *ensure that emissions reductions are genuine*
- *develop methods for calculating emissions reductions from priority activities*
- *facilitate the aggregation of emissions reductions across projects and activities.*

Response:
Extract – page 48 *The Emissions Reduction Fund will be built on the Carbon Farming Initiative by expanding its coverage beyond the land sector to enable the Clean Energy Regulator* ***to credit emissions reductions from across the economy*** *(see Chapter 2). There is also potential to streamline the Carbon Farming Initiative arrangements for assessing methodologies and approving projects. Building on the Carbon Farming Initiative will be a simple way to implement the Emissions Reduction Fund and will provide continuity for business.*

I read this extract to assume that emissions reduction beyond the terrestrial landscape will be fully considered. Following details refer to "blue carbon" –

emissions reduction using Australia's most productive ecosystems, our coastal intertidal and sub-tidal resources.

1 – Genuine Investments

In terms of "blue carbon" the key way to ensure emissions reductions are genuine is to focus investment on repair activities – that is to re-create productive and sustainable coastal landscapes where for whatever reason these have been lost. That is, to go beyond current "business as usual" and invest in those repair works that will foster emissions reduction by re-establishing productivity - seagrasses, salt marshes, fresh to brackish wetlands and mangroves. All the secondary benefits that repairing these landscapes provide such as seafood, export income and jobs will also result. Some examples of investment opportunities include:

- ***Re-establishing tidal flows*** – the tide is a key driver of coastal system productivity; Culverts under road causeways, enlarged bridges to foster more tidal flow, manipulations to entrance training walls, removal of non-essential flood levees and re-construction of smarter flood barrages will all foster greater tidal ventilation and thereby sequester carbon.
- ***Re-creating tidal salt marsh and mangrove wetlands*** – land shaping such as ponded pasture development along the tropical coasts of Australia generally did not create more grazing land. They simply created wastelands and markedly reduced such as prawn productivity. Removal of ponded pastures and re-creation of tidal environments and wetlands will sequester carbon very cheaply, along with the multiple other benefits of fisheries productivity.
- ***Re-creating fresh to brackish floodplain wetlands*** – South west WA, Tasmania, Victoria, NSW and Qld all have substantial floodplain wetland areas that were barraged and drained in an attempt to create additional agricultural lands. As with ponded pastures, mostly the result has been to create non-productive wastelands, that emit fish killing acid sulphates into the estuaries during rain events and greenhouse gas methane into the atmosphere during dry periods. Smart repair of these landscapes will minimise methane emissions, improve water quality, sequester carbon and of course markedly improve fisheries productivity – think school, eastern king, tiger and banana prawns, mulloway, mullet and flathead.

[Further site specific detail of opportunities for repair is provided in the references listed at the end of this submission – especially - http://frdc.com.au/research/Documents/2012-036-Business-Case.pdf]

2. Quantification of Emissions Reductions

For" blue carbon" there has been sufficient research to be able to broadly quantify the sequestration opportunities for various landscape types. See the synthesis of information in http://frdc.com.au/research/final-reports/Pages/2011-084-DLD.aspx which provides the Final Report of: ***Optimising and managing coastal carbon: comparative sequestration and mitigation opportunities across Australia's landscapes and land*** including preliminary estimates of carbon sequestration rates in Australian coastal landscapes and a detailed reference list of Australian and international research and findings to mid 2013.

Nevertheless further R&D is recommended to more specifically quantify carbon sequestration. This is probably best done as a parallel R&D activity to investment in repair works.

Indeed for many if not all, prospective emissions reduction opportunities there will be a dearth of knowledge on emissions reductions profiles.

SUGGESTION - THAT FOR VIRTUALLY ALL EMISSIONS REDUCTIONS INVESTMENTS THAT MONITORING OF CARBON PROFILES, CARBON SEQUESTRATION RATES AND OTHER KEY BENEFITS TO THE AUSTRALIAN ECONOMY ACCOMPANY THE EMISSIONS REDUCTION FUND INVESTMENTS.

This will ensure the Australian investments stand up to scrutiny, whether that scrutiny is for international accounting purposes, Australian financial and performance audits or even politically motivated assessment by detractors of the proposed scheme.

It would be relatively simple to design such a monitoring and reporting initiative as long as the focus remains on the outputs and outcomes and moves well away from the complex and contorted methodology systems that plagued previous activities.

3. Facilitate Aggregation across Projects

Extract – page 50 *To streamline method development under the Emissions Reduction Fund and ensure that large emissions reduction opportunities from across the economy can bid into the Emissions Reduction Fund, the following process improvements will be considered:*

- *establishing clear priorities for methodology development in consultation with industry, abolishing the positive list and addressing additionality through methods*
- *simplifying methods and, where possible, incorporating models and processes used in the National Inventory*
- *improving transparency by releasing draft methods in their final form for public consultation, and reducing the consultation period from 40 to 28 days.*

AND

Extract page 51
5.2.2 Project approval and aggregation

There will also be opportunities to streamline Carbon Farming Initiative project approval processes and aggregation.
Carbon Farming Initiative projects are approved by the Clean Energy Regulator. Forestry and soil carbon projects can be approved only if the project developer owns the land or has another relevant property right, such as a lease or carbon property right. Under the current arrangements it might be difficult to aggregate projects because landholders who would otherwise participate may be unwilling to

transfer property rights to a project aggregator. Aggregation would be easier if, instead, the project aggregator needed only to demonstrate that they have the agreement of landholders to take part in the project. This will also make participation more attractive by enabling risks and transaction costs to be shared across multiple properties and property owners.
Other approaches to supporting project aggregation will also be considered.

I understand this detail to suggest that there is no set paradigm for the Emissions Reduction Fund. Most importantly, that public-private partnership can be part of the scheme and that beneficiaries may be the entire Australian community, as indeed will be the case if we invest in repairing our coastal resources. This leads me to further explore how "blue carbon" emissions reduction may be best implemented.

Aggregation if done well should reduce transaction costs and deliver larger outcomes. For "blue carbon" aggregation levels are as follows:

- **first order biophysical** - the specific wetland / coastal waterbody area
- **second order biophysical** - the estuary or embayment catchment is the component for aggregation. [Such an approach has been taken in the Business Plan for estuary repair as previously referenced.]
- **first order institutional** – Local Government Area
- **second order institutional** – coastal NRM regions
- **third order institutional** – state, preferably in some form of Trust arrangement.

These hierarchies recognise that emissions reduction will be on both private and public lands / waterways and that any payments would also need to reflect this multi-partner ownership nature of these coastal resources. Public-private partnerships will be essential. Financial systems that foster integrated coastal repair and are managed as a key opportunity for ongoing investment and management through state-by-state Trusts are recommended.

It is also recommended that such a tiered approach be implemented for aggregating "blue carbon" investments in terms of investment and benefits analysis, monitoring and reporting.

Initially the Clean Energy Regulator could run relatively frequent tender rounds to bring forward the delivery of emissions reductions.

The Clean Energy Regulator would apply a benchmark price — the maximum amount it would pay per tonne of emissions reduced — with only bids costing less than the benchmark price being considered.

Views are sought on how best to:

- *facilitate early participation in the Emissions Reduction Fund*
- *operate an efficient auction process to secure lowest-cost emissions reductions.*

Response:
This Scheme requires vision and leadership, not lowest common denominator tender type approaches. The Australian community seeks expert delivery systems and leadership from its Governments with outcomes to both private and public beneficiaries.

I suggest there are too much at stake and too many multiple benefits that could result from a well-run scheme and its set of investments to allow this opportunity to denigrate into lowest cost tender type processes.

It is my opinion that tender type processes abrogates the responsibility of Government in articulating the vision and leading the Australian community towards a healthier more sustainable vibrant economy, social well-being and environmental quality.

Standard contracts will be used to guarantee payments for verified emissions reductions. These would have a maximum duration of five years and include options for addressing under-delivery of emissions reductions.

Views are sought on how best to provide:

- *funding certainty for businesses*
- *confidence that projected emissions reductions will be delivered.*

Response:
The "blue carbon" opportunity is both a public and private benefit. For this scheme to deliver to the Australian community, delivering as well as emissions reduction benefits other benefits such as long term jobs, food and improved Australian lifestyle then Trust-type arrangements would be necessary for each state and its coastal resources. Such arrangements go well beyond 5 years and if done well, can generate their ongoing investment stream so that across carbon and all other key benefits these Trusts can be self-sustaining for the benefit of the Australian community forever.

While such a vision does deliver the lowest-cost emissions reductions of all Australian landscape related opportunities, perhaps this concept is far too advanced for the constraints of the current scheme and the current scheme's unfortunately, still too close an alignment with Kyoto and related international protocols.

A safeguard mechanism will be introduced to provide incentives to reduce emissions above historical business-as-usual levels.

Views are sought on:

- *the coverage of the mechanism*
- *how baselines could most easily be set to effectively limit increases in historical business-as-usual emissions*
- *the treatment of new entrants and significant expansions, including definitions of best practice*
- *compliance options in the event that baselines are exceeded.*

Response:
Much of this issue has been covered previously.

For "blue carbon" as detailed previously in this submission, we are seeking to optimise the returns that the Australian coastal landscape can provide to the Australian community in food and lifestyle benefits forever.

Investment in repair of coastal productivity has a clear baseline of current poor condition and a clear outcome of improved condition / carbon capture. Both are fully measurable and the results would stand any level of scrutiny – be it international, performance audit based or politically motivated.

The Emissions Reduction Fund will build on and streamline the existing architecture of the Carbon Farming Initiative.

Views are sought on:

- *options for streamlining the Carbon Farming Initiative*
- *how best to encourage the uptake of land sector activities.*

Response:
The Carbon Farming Initiative could be perceived as yet another consequence of adherence to Kyoto and related protocols under a prior Government that in its vigour to join the international community was perhaps somewhat blinkered as to what comprises Australian conditions and practical opportunities. The "planted trees" only construct of Kyoto has already been noted in the introduction as an example of how Kyoto is lacking in understanding of the Australian environment and its particular opportunities.

Equally importantly, the methodologies developed under the CFI were not pragmatic and easily implementable to the benefit of the participating landowners. As discussed in my previous submission and quoted in this Green Paper, it is essential that all measurement and reporting systems build on understanding best practice, probably are somewhat conservative as to the level of carbon sequestered and ensure that the benefits of landowner participation are not all lost in costly third party monitoring and reporting activities. Australia and its landowners cannot afford the types of administrative overkill that seems to plague EU-type schemes.

It is strongly suggested that Australia move well beyond the limited construct that was Kyoto and set up an Emissions Reduction Scheme that best delivers to Australia, its landscapes and its communities. To do so will mean a rethink on all methodologies within the CFI and of course a rethink as to which opportunities can be part of the CFI.

SUGGESTION - "BLUE CARBON" BE INCLUDED IN A RETHINK AS TO WHAT IS ELIGIBLE - EITHER AS PART OF CFI OR, AS A SEPARATE STAND ALONE COMPONENT TO THE AUSTRALIAN APPROACH OF EMISSIONS REDUCTION.

The Emissions Reduction Fund will be administered by the Clean Energy Regulator.

Views are sought on the proposed governance arrangements.

Response:
Somewhat beyond the remit for this submission.

Perhaps the key comment I can offer is to make sure that the proposed governance arrangements look across Government policy and Australian community expectations. Single purpose policies are generally sub-optimum in their delivery to Australia's economic growth, social well-being and environmental condition.

The Government will conduct a review of the Emissions Reduction Fund towards the end of 2015 so as to provide certainty about the policy and design intent post-2020.

Views are sought on the timing and conduct of a review.

As above – essential any review is undertaken in the context of Australia's economic growth, social well-being and environmental condition

3. Building a "Blue Carbon" component to Australia's Emission Reduction Fund

Recognising that:

- "blue carbon" is well beyond the construct of existing international agreements at this stage,
- that this Green Paper is largely built around that international construct and,
- that, as the Coalition policies have suggested, its time Australia demonstrated a pragmatic approach to emissions reduction,

the following brief sections outline how Australia might take leadership in demonstrating smart emissions reduction that also delivers multiple other benefits to the Australian community.

3.1 Enabling Policy for "blue carbon"

Key elements of an enabling policy are likely to include -

- recognise that coastal intertidal and sub-tidal ecosystems provide the highest per hectare carbon sequestration opportunity across the suite of Australian landscape related opportunities [natural landscapes and agricultural / grazing / forestry landscapes]
- recognise that much of the opportunity lies within public lands, most tidal and subtidal lands being within some form of trustee management arrangements to Local and State Governments and their various agencies
- recognise that many of the wetland areas, disturbed, drained and emitting methane are in private or leasehold tenure so that there is a private component to the target areas for repair
- incorporate financial and administrative systems to aggregate and where necessary distribute benefits across public-private partnerships
- make provisions to attract third party investors, such as those seeking offsets for their coastal developments
- foster smart monitoring and reporting systems that are undertaken in parallel with works and detail by landscape type aggregate conservative accounts of carbon change and $ worth
- foster smart monitoring of key other benefits such as enhanced fishery productivity, ensuring that these benefit streams are also translated into estimates of increased $ worth and revenue generation systems
- empower ongoing Trust arrangements, possibly state or regionally based
- provide for some form of benefit transfer systems that across all key benefit streams deliver resources to these Trusts so that further works and management can continue in perpetuity
- link and embed Trust arrangements with all existing key legislative and regulatory frameworks in each state

3.2 A staged approach to implementation

Implementation will take time and most importantly leadership from the Australian Government. Key elements are likely to include:

- Australia-wide group to steer all activities towards implementation – policy, R&D, activities, communication, delivery
- Policy development, including such as Green Paper processes for community and Government consultation and involvement
- Further information collation on the benefit streams as part of building the all encompassing Business Case for action
- Ongoing R&D to ensure accurate quantification of benefit streams
- Development of model provisions for such as Trusts and public-private partnerships
- Oversight of implementation, reporting progress and outcomes

This will take time, will need to be staged and will need to be inclusive in approach – but the benefits to the Australian community in emissions reduction, coastal lifestyle, increased and sustainable food production and in regional jobs in all aspects of the professional and recreational fishing industries and tourism are substantial.

3.3 Further Information

http://frdc.com.au/research/Documents/2012-036-Business-Case.pdf provides the detailed Business Case for ***Revitalising Australia's Estuaries*** and demonstrates that even without considering the carbon sequestration benefits the proposed investment of $350M is returned in less than 5 years

http://frdc.com.au/research/final-reports/Pages/2011-084-DLD.aspx provides the Final Report of: ***Optimising and managing coastal carbon: comparative sequestration and mitigation opportunities across Australia's landscapes and land*** including preliminary estimates of carbon sequestration rates in Australian coastal landscapes and a detailed reference list of Australian and international research and findings to mid 2013.

Fisheries Habitat – where to invest?

Some thoughts on beneficiaries, opportunities, strategic priorities and outputs we seek from this meeting

The beneficiaries

- Wild **fisheries** – increased productivity + resilience to various shocks [eg climate, overfishing, land use]
- Professional and recreational **fishers** – industry growth in both sectors is possible...and always there will be resource partitioning / sharing / conservation
- GBR & Qld **ecosystem** health / biodiversity / endangered spp / food webs + flow-ons to tropical Australia

Our long term goals -

- More productive fisheries
- Enduring habitat protection, repair and management
- Net improvements in ecological health as a linked set of ecosystems

Contributing long term outputs we seek

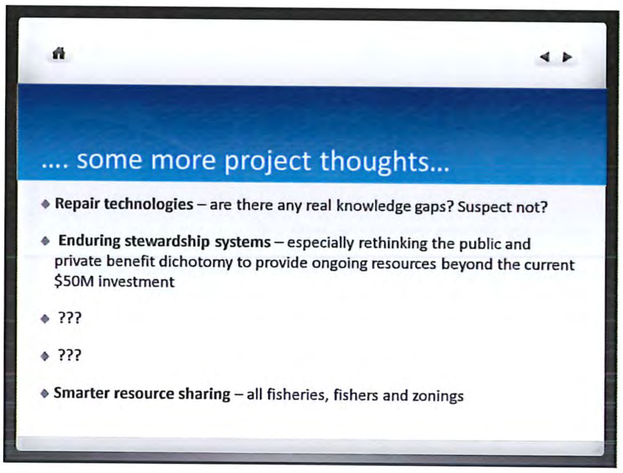
- **Skills** - High capacity ongoing R&D support for smart habitat protection, repair and management
- **$ resources** - Continued investment in repair works and management
- **Policy & commitment** - Systems and processes in place to ensure "net increase" from the current low base....while recognising there will be local losses a/c development

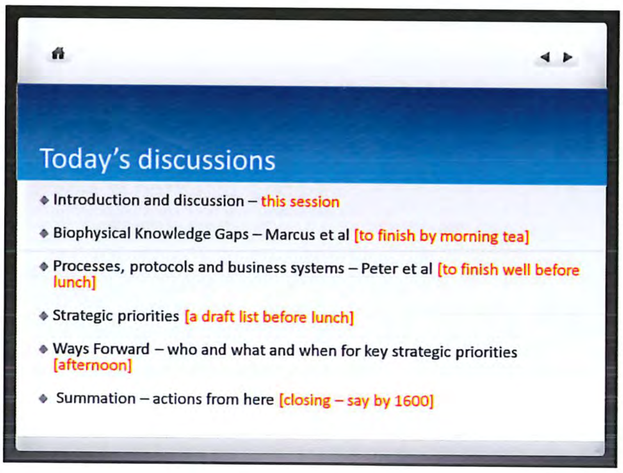
Current opportunities - starting to line up

- $350K to allocate to R&D ex Qld FRAB
- $40M in rural "systems repair" + $10M in urban "systems repair"....this is NOT R&D but it provides a great laboratory!
- NRM groups to re-do their Water Quality Improvement Plans – putting fish back in the water!
- R&D for Reef Rescue yet to be announced
- Private sector needs for knowledge driven "net gain"

Structuring & defining some strategic investment? – some project thoughts

- **Key site identification** – for industry investments in offsets and for the $50M repair program – all predicated on Return on Investment analysis to optimise benefits both public and private from coastal landscapes
- **Habitat Specific Metrics**....eg repairing ponded pastures to fisheries habitat; re-establishing tidal flows; re-connecting fresh to brackish habitat to tidal
- **Science based monitoring**...it will be at least 5% of the $50M = abt $2.5M
- **Knowledge gaps we MUST fill**.....MUST = roadblocks to action. What are these? [eg – see Lit Survey]


.... some more project thoughts...
Repair technologies – are there any real knowledge gaps? Suspect not?
Enduring stewardship systems – especially rethinking the public and private benefit dichotomy to provide ongoing resources beyond the current $50M investment
???
???
Smarter resource sharing – all fisheries, fishers and zonings


Today's discussions
Introduction and discussion – this session
Biophysical Knowledge Gaps – Marcus et al [to finish by morning tea]
Processes, protocols and business systems – Peter et al [to finish well before lunch]
Strategic priorities [a draft list before lunch]
Ways Forward – who and what and when for key strategic priorities [afternoon]
Summation – actions from here [closing – say by 1600]

Reef Trust – a great idea for all Australia's coasts

The Discussion Paper for the proposed Reef Trust was recently released *[add URL for Dept Envt Discussion Paper]*. Certainly an increased focus on repair and protection of the Great Barrier Reef coastal zone is well justified [*add URL for Colin's GBR Repair Strategy]*. But why stop there? Multiple studies at local to regional scale and the only national assessment *[add URL National Land and Water Resources Audit]* all demonstrate the loss of coastal productivity and the need to strategically invest in repair and protective management of Australia's coastal resources.

So why beyond the GBR?

In brief – most of us live near the coast; well over 15% of us claim to recreationally fish; boating, sailing, canoeing, swimming and nature appreciation are all high use recreational pursuits; and most of us enjoy seafood as part of a healthy diet. Yet wherever we reside, work and play our endeavours have taken a huge toll on the productivity of our estuaries and embayments. Agriculture, urban development, infrastructure and industry all have played their part in affecting fisheries habitat, biodiversity and water quality. The Audit of 2002 found....There is no reason to believe a lot has improved since this last nation-wide assessment.

Can anything be usefully achieved? Repair – Business case

Why another layer of management?

So what should the criteria be for Trusts?

And their investment streams?

What does success look like – state by state

National Environmental Science Program
Repairing Estuary and Inshore Productivity
Fish, Food and Jobs - Forever

1. Recommendation

That the Australian Government funds under NESP a science initiative that underpins and fosters the repair of our key coastal assets.

As already well demonstrated in similar USA and EU initiatives, flow on benefits will be substantial - ecologically, economically and socially.

Outcomes - healthy high quality seafood, enhanced urban & coastal lifestyle, re-established habitat for rare & endangered birds & vegetation, world heritage area repair, improved flood management and increased regional employment.

2. The Problem

Our estuaries and embayments are globally the most productive ecosystems – yet in southern and eastern Australia they are our most degraded ecosystems with substantial looses in their productivity across all species, fish and other biota kills, loss of habitat, hypoxia and damaging floods. Examples include:

- **Salt marshes and fresh to brackish wetlands** - once ubiquitous around southern and eastern Australian floodplain and coastal landscapes are now regarded as endangered ecosystems in several states – e.g. NSW
- **The Lower Lakes, Coorong and lower Murray** - once Australia's largest estuary, supporting masses of migratory waders, waterfowl and fish such as mulloway. There were once 100 mulloway commercial fishers in the Coorong supplying Adelaide with most of its seafood needs. That part of this area is still classified as World Heritage attests to the resilience of coastal ecosystems.
- **Shellfish reefs** - once existed in sheltered waters from Moreton Bay right around to Albany and in D'Encastreax Channel in Tasmania. These reefs provided massive 3 dimensional habitats and most importantly were in situ water purification systems. They are now scientifically classified as "functionally extinct"
- *Mugil cephalus,* **Sea Mullet** - even Australia's highly fecund, algae feeding, bottom of the ecosystem fish species is in decline. When what could be considered as "Australia's native carp" is in trouble its definitely time we invested in repair
- **School Prawns** - several species from WA and the Swan [as detailed as part of the previous Perth lifestyle in Tim Winton's "Cloud Street"] or in the Shoalhaven in southern NSW are virtually locally extinct.....yet these are highly fecund annual stocks that have lost out to loss of habitat, especially salt marshes, seagrasses and fresh to brackish wetlands.
- **2013 Clarence flood** – causing massive costs and insurance claims due to the lack of wetlands as detention basins, these same drained wetlands caused acid sulphate killing fields. The entire benthos of bottom dwelling worms, bivalves, amphipods and so on, the very bottom of the biodiversity food chain, were all killed. Sediment sampling could not detect anything alive from Grafton, just below the tidal limit to the ocean at Yamba

3. Return on Investment

Creighton and team in 2013 [http://frdc.com.au/research/Documents/2012-036-Business-Case.pdf] calculated an initial investment in repair works of $350M would be repaid, just based on increased productivity of selected commercial catch in well less than 5 years.

This proposal suggests that the NESP fund the R&D component as part of the transition to more productive and biodiverse estuarine and inshore environments for the multiple benefits they provide to the Australian community.

4. Synergies

The US Nature Conservancy has started to foster repair of Australian estuaries based on the highly successful activities in the USA. Its first investment is the seed funding to re-establish oyster and mussel reefs in Port Phillip – essential for improved insitu water purification and habitat for the commercially and recreationally important snapper, along with of course many other species of fish, crustacean and birds.

Work is underway to define how best to undertake R&D to foster increased productivity across the primary industries sectors. This is part of work towards the election commitment of $100m for RDC's and may be a useful co-funder.

Many State governments, including SA, Vic, NSW and QLD already reallocate revenue collected from recreational fishing licences / boat registrations to improving recreational experiences. As the various community groups recognise, the key part of the experience needing investment is re-establishing healthy and biodiverse ecosystems. Several states are likely to offer to partner with a NESP initiative.

5. R&D priorities

Priorities for improved knowledge fall into two broad categories –

- Ecosystem ecology and responses to repair
- Human interactions and opportunities for improved ecosystem productivity and management

The attachment summarises the underpinning concepts and the likely broad areas of R&D investment.

6. Further Information

Australia-wide overview – Colin Creighton, colinmwnrm@bigpond.com; mobile - 0418 225894; home 07 49584775
University leadership, Murray and SA Gulfs – Justin Brookes
Justin.brookes@adelaide.edu.au 0418 898782
Port Phillip oyster and mussel reefs and the Nature Conservancy funded repair initiative – Paul Hamer paul.hamer@dpi.vic.gov.au 0409 334395

Attachment: *R&D Priorities – Australia's estuaries, embayments and nearshore marine environments*

Australian Centre for Estuaries and Coastal Productivity

Growing Australia's Fish Stocks

The value of fish to Australia

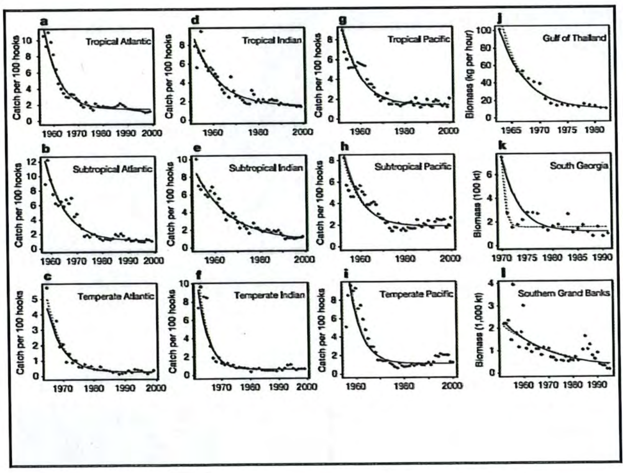
- $18.7 billion pa, marine tourism/recreation
- $2 billion pa, commercial fishing+aquaculture
- 11,600 people employed in commercial
- 3.4 million Australians include recreational fishing as part of their lifestyle
- 16kg of fish/seafood pa per person consumed

Problem Statement

- **Losing fisheries** on a nation-wide scale
- Australia is now a **net importer** of seafood
- Total Australian wildcatch **production fell 1%** in 20092010
- '**Shifting baselines**' of expectations
- Increasing **global demand** for high quality products

We could be catching more fish!

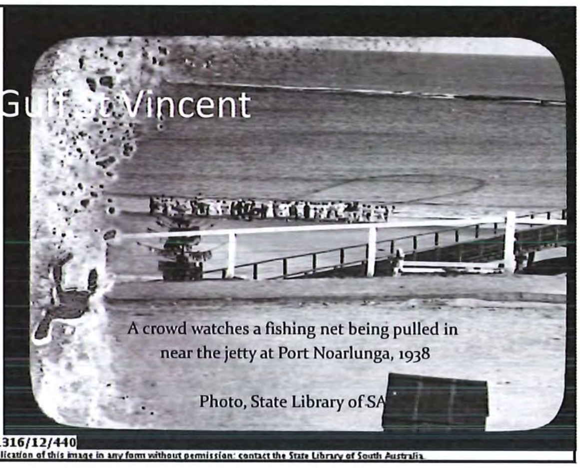
- The productivity of Australia's estuaries, coasts and oceans could be MUCH higher
  - Large predatory fish are perhaps 10% of their pre-industrial population levels
  - Herds of dugong off the east coast were km long
  - Major fisheries close to cities now gone
  - Recreational fishers having to travel further



Where have we come from?

- Historic photos of fishing catch
  - Gulf St Vincent, SA
  - Coorong and Murray Mouth, SA
  - Coastal NSW

Gulf St Vincent



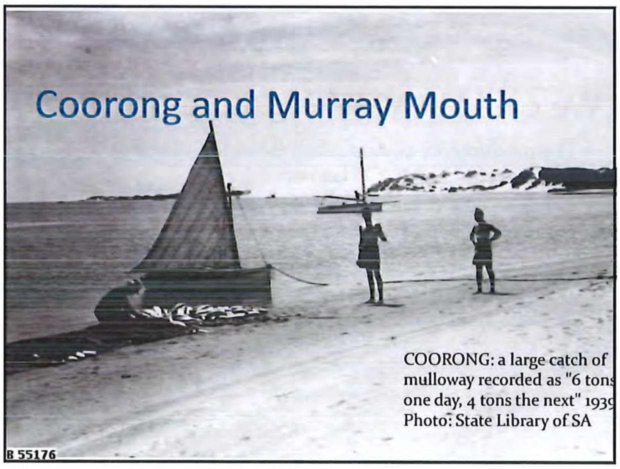
A crowd watches a fishing net being pulled in near the jetty at Port Noarlunga, 1938

Photo, State Library of SA

Gu

Fishing catch at Sellicks Beach, S. Aust., circa 1930s
Photo: Onkaparinga Library

Coorong and Murray Mouth



COORONG: a large catch of mulloway recorded as "6 tons one day, 4 tons the next" 1939
Photo: State Library of SA

Coorong and Murray Mouth

Fishing catch and fishermen John (Jack) Peter Graney and C. Pavy at Milang jetty
Photo: State Library of SA

Coorong and Murray Mouth

Andy Ross's catch of butterfish filling a small rowboat, at Nine Mile Point, The Coorong, 1938

Photo: State Library of SA

Coastal NSW

Fishing at North Shore, Hastings River.
About 100 whiting thread on a vine

(State Library of NSW)

Coastal NSW

Hauling in the catch, Coolangatta Beach, 1938
State Library of NSW.

Coastal NSW

Part of a 3½ ton sea mullet haul from Boambee Creek, near Coffs Harbour

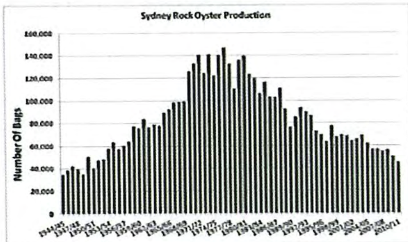
Coastal NSW

From the collections of the Wollongong City Library and the Illawarra Historical Society

Coastal NSW

Oysters were once abundant

Sydney Rock Oysters



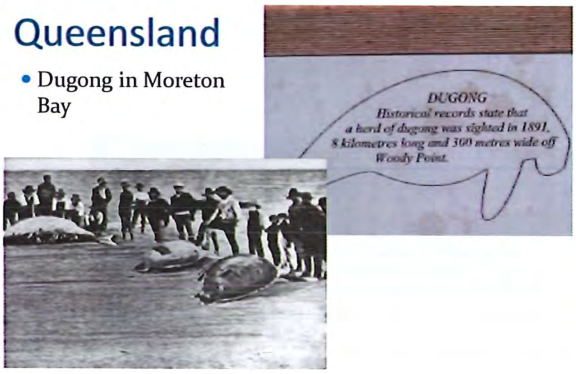
- Major production losses post 1970's relate to decline in estuary health, even though production techniques have improved.
- *Lisa Kirkendale, Pia Winberg, Ana Rubio, Peter Middelfart (in prep), "The Australian oyster industry: Challenges and Opportunities"* Reviews in Aquaculture

Queensland

- **Large Sawfish caught in Queensland, 1921**

Queensland

- Dugong in Moreton Bay



South East Queensland

South East Queensland

Oyster Bank, Toorbul Point, 1906
Photo from John Oxley Library (courtesy Diggles 2013).

Loss of oyster reef beds

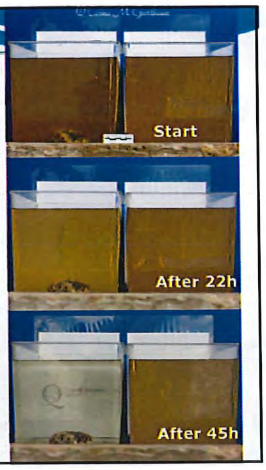
Why are our fish stocks so low?

- Over fishing – largely addressed with quotas
- Water quality – being addressed and improving
- **Habitat degradation**
  - **Drainage of wetlands**
  - **River regulation**
  - **Flood mitigation**
  - **Nutrients and sediment run-off**
  - **Altered pH**
  - **Salinity**

Estuaries and coastal wetlands

- Fish species that are dependent on a life cycle phase within estuaries and wetlands
  - Virtually all Australia's recreational species
  - 70% to 80% of commercial species
- Both tidal and freshwater flows are essential
- Works that will be of substantial benefit
  - re-establishing connectivity
  - repair habitats where they are in poor condition
  - improve the physical drivers of tidal and freshwater flows and fluxes with their accompanying nutrients
  - Re-establishing the filter feeders

Filtering capacity of a horse mussel



Would it be worthwhile restoring habitats that support Australia's fisheries?

Cost:Benefit Analysis

- Selected fisheries :
  - A single regional fishery, Murray + Coorong,
    - Mulloway, Black Bream, Greenback Flounder and Yelloweye Mullet.
  - A state, New South Wales,
    - Sydney Rock Oyster, School Prawn and Mullet
  - An iconic region, the Great Barrier Reef
    - Banana Prawns and Tiger Prawns.

Assumptions

- No non-market values included in analysis
- Analysis starts at Year 5 and assumes close to full biological response by that time.
- Demand is assumed to be totally elastic.
- No estimated increases in value factored in.
- Current partitioning of stock between wild-caught professional product, recreational catch and remaining wild population is estimated.

Coorong and Murray Mouth

- Commercial fishery worth $5.7 million pa
  - Mulloway, Yelloweye Mullet, Black Bream, Greenback Flounder
- Productivity improvements 20%: $260,000 pa
- Break-even point: less than 7 years

Coorong and Murray Mouth

- Re-establish connection to creeks and rivers
- Reconfigure wetlands and water ways
- Return salt marshes
- Improve fish passage across the barrages

Images courtesy of wetlandwanderer

Coastal NSW

- Commercial fishery worth $xx million pa
  - Sydney Rock Oyster, Mullet, School Prawn
- Productivity value increase at least $94M pa
- Break-even point - less than 3 years

Images courtesy of DPI NSW

Coastal NSW

- Improve quality of waters entering estuaries from rivers
- Restore oyster beds

Images courtesy of Earth Repair

Great Barrier Reef

- Commercial fishery worth $xx million pa
  - Barramundi, Banana Prawns, Tiger Prawns
- Productivity value increase at least $45M pa
- Break-even point - less than 2 years

Image: The Morning Bulletin

DAFF Queensland

Great Barrier Reef

- Create fish passage in Fitzroy River
- Restore wetlands and seagrass beds
- Reduce sediment outflows
- Restore oyster beds

Images: Fitzroy Weirs James Cook University Seagrass Watch

How?

Actions	Cost	
Planning	$21 m	6%
Works	$238 m	68%
Monitoring	$24.5 m	7%
Reporting	$10.5 m	3%
Communications and marketing	$17.5 m	5%
Policy development	$17.5 m	5%
Researching	$21 m	6%
TOTAL	$350 m	

National areas of focus

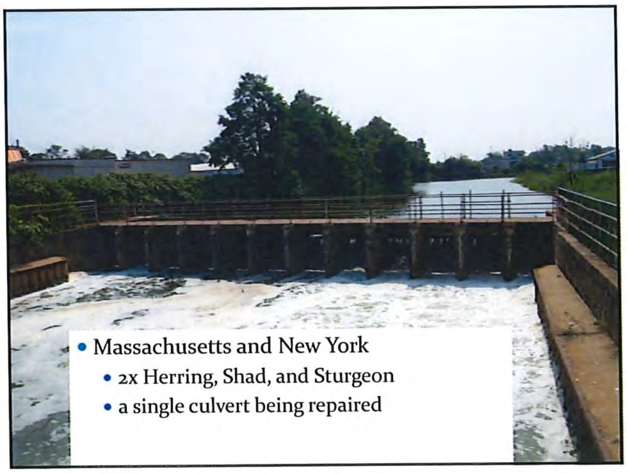
- Great Barrier Reef
- South East Queensland
- New South Wales floodplain estuaries
- Victorian and Tasmanian wetlands, mussel & oyster reefs
- South Australia:
  - Lower Murray and Coorong,
  - the Gulfs,
  - Coastal Salt Marsh complexes,
  - South East coastal lakes of Lake Bonney and Lake George.
- Western Australian estuaries
- Darwin Harbour

Has this been done before?

- USA
  - Chesapeake Bay
  - Massachusetts
  - San Francisco Bay
- Australia
  - Lake Wallis, NSW

How fast?

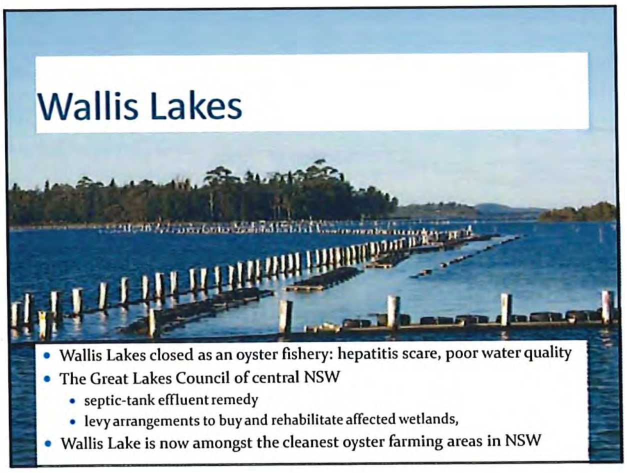
- Chesapeake Bay, Maryland, USA
  - 57x increase in oysters in 5 yrs
  - 35 ha of rehab



- Massachusetts and New York
  - 2x Herring, Shad, and Sturgeon
  - a single culvert being repaired

- San Francisco Bay,
  - rehabilitated salt marshes
  - measured response from 41 fish spp in months

Wallis Lakes



- Wallis Lakes closed as an oyster fishery: hepatitis scare, poor water quality
- The Great Lakes Council of central NSW
  - septic-tank effluent remedy
  - levy arrangements to buy and rehabilitate affected wetlands,
- Wallis Lake is now amongst the cleanest oyster farming areas in NSW

Research Program Outputs

- Guidelines to optimise estuarine management
  - Link catchment hydrology and productivity of estuaries
  - Link habitat condition to sustainable yield
  - Identify key nursery areas and how best to manage
  - Guidelines for repair of estuaries
- Develop resource sharing guidelines
  - Review potential carrying capacity
  - Economic assessment of cost and benefits
  - Models for cost sharing habitat management
- Toolkit for stakeholder engagement

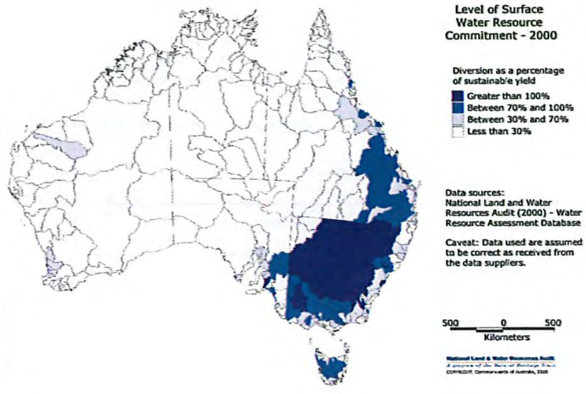
Project materials developed

Fishers and community

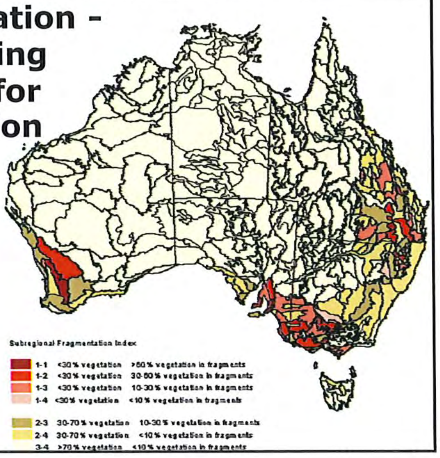
- Adaptation case studies [PowerPoint]
- Fish March 2014 – *Habitat: a high yielding investment*
- Fish June 2013 – *Reconnect to revitalise fisheries*
- Natural resource management and coastal ecosystems [PowerPoint]
- Fact Sheet – *Adapting to a changing climate* [with 6 accompanying issue-specific Fact Sheets prepared for key projects through working with and supporting Principal Investigators – Atlantis and SE project]
- Paradigm shifts [PowerPoint]
- Recreational Fishing Group Multi-state template [PowerPoint]
- VRecFish Newsletter - featuring habitat
- VRecFish presentation -featuring shellfish reefs [PowerPoint]

Science & Policy – some example case studies

- Water use sustainability
- Investment in landscape repair
- $1.4B National Action Plan for Salinity & Water Quality
- Marine Bioregionalisation & Representative Conservation
- $200M Reef Rescue
- Blue Carbon – a work in progress



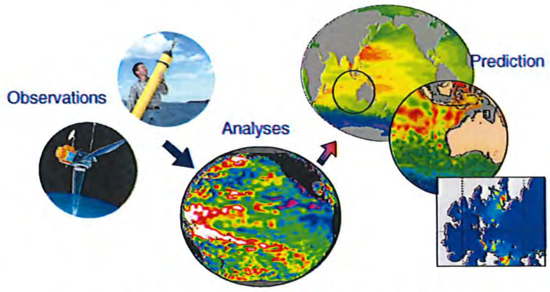
Fragmentation - investigating priorities for revegetation



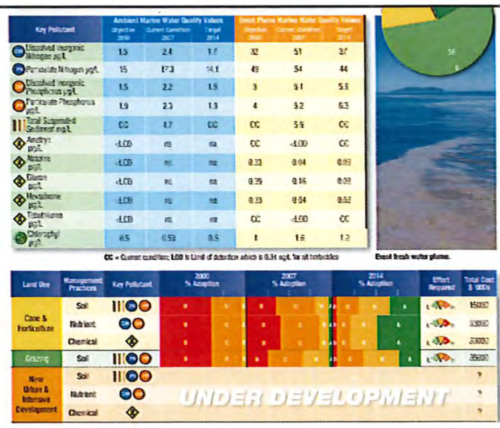
Sediment export to Great Barrier Reef Lagoon -Fitzroy Basin

Sediment: 21 times natural at 2,635,000 tonnes per year with 63% from sheet and rill erosion, particularly from grazing landscapes

Observation, Analysis, and Prediction System
Ocean Knowledge Warehouse



Ocean Warehouse ⇒ Client Delivery



Goal	Repair and management of key estuary and wetland habitats for multiple objectives - carbon sequestration; biodiversity; coastal water quality; sea level change; fishery productivity.		
Context – *how important are coastal ecosystems in carbon sequestration compared to other Australian environments?*			
Project - Comparative Sequestration Opportunities			
Policy - **Forum to facilitate policy debate in partnership with Adaptation Network**			
Output	**Policy Briefs and draft Science Papers**		
Measurement - **Accounting Carbon** – *how can we cost-effectively measure sequestration benefits as part of the Carbon Economy?*		**Works** - **Repair opportunities** – *where and how can we cost effectively repair estuaries and coastal wetlands for the multi-objectives outcomes we seek?*	
Proposal	DAFF – Filling the Research Gap	**Proposal**	SEWPaC Biodiversity Fund –
Output	Participation in carbon Economy	**Output**	Plan for action
Program – Estuary & Wetland Repair			

Key Elements

Integrated and multi-disciplinary science – "program science"
Clear knowledge need and support for outcomes
Explicit policy application....and buy-in
Engagement
Quality and defendable science outputs including certainty!
Distillation into key messages
Timing
Vision

By Catherine Norwood

FRDC Research Code: 2012/036
More information: Colin Creighton, 07 4958 4775; http://frdc.com.au/research/Documents/2012-036-Business-Case.pdf

Healthy Blue Mussel reefs still exist in Gippsland and could be restored in areas such as Port Phillip Bay.

Habitat: a high-yielding investment

Improving the productivity of fisheries is one thing commercial, recreational and Indigenous fishers are all in favour of – repairing estuaries provides the opportunity to do just that

PHOTO BRENT WOMERSLEY

A $350 million investment in estuarine habitat restoration would be recouped in five years through increased fisheries productivity according to a new cost-benefit analysis that identifies a national program of priority works.

The report *Revitalising Australia's Estuaries* uses three case studies to estimate potential returns on investment. The scope of potential works outlined in the report includes more than just those in the case study regions, and overall return on investment would be much greater than the case study estimates alone.

For the report's senior author, Colin Creighton, such an investment represents infrastructure development as much as it does environmental restoration, with long-term returns to fishers, jobs and the Australian community.

"This is not surprising when it is recognised that our estuaries are our most productive ecosystems and the demand for food, for enhanced recreational experiences, for Indigenous take and for improved biodiversity are all growing," he says.

The case study fisheries are the Coorong at the mouth of the River Murray in South Australia, the floodplains of the Great Barrier Reef in Queensland, and New South Wales' major estuaries.

In addition to more productive fisheries, habitat restoration would improve coastal water quality, enhance catchment hydrology and repair coastal biodiversity. It would also finetune flood control, re-establish carbon sequestration and reinforce foreshore buffering against extreme events. None of these additional benefits have been costed.

"Our estimates suggest a break-even for investment just from increased fisheries product is well less than five years and from then on benefits of more seafood exceed costs forever."

The analysis, which was funded by the FRDC and the Australian Government Biodiversity Fund, received widespread support and input from state and federal fisheries and conservation agencies, as well as the fishing industry, and research and Indigenous groups.

The bulk of the proposed investment – $238 million – would be spent on infrastructure works to restore connectivity of estuarine systems, such as fish passages, wetland acquisition and repair, and complementary works to ensure smarter floodplain and estuarine systems.

Planning, monitoring and communication are included in the cost estimate, along with funding to support the development of consistent policy and regulations in each state for estuarine and nearshore habitat protection, repair and for development offsets.

Coorong

In the Coorong, the financial analysis, led by Justin Brookes from the University of Adelaide, has been based on increased returns from potential increases in Mulloway (*Argyrosomus hololepidotus*), Yelloweye Mullet (*Aldrichetta forsteri*), Black Bream (*Acanthopagrus butcheri*) and Greenback Flounder (*Rhombosolea tapirina*). Numerous other species, including Pipis (*Donax* spp.), could also be expected to benefit. The Coorong commercial fishery has a current annual economic value of $5.7 million.

Estimated fishery productivity improvements of 20 per cent across all key species could lead to comparable increases in the annual economic value. "While the fishery is comparatively small, the economic and employment benefits to the regional community are substantial," Justin Brookes says. "The total estimated increase in the value of productivity for these selected species following the completion of identified works is at least $260,0000 a year."

Other major benefits would include increased fisheries productivity for recreational fishers, protection of the biodiversity in this listed World Heritage Area, increased tourism and protection of Indigenous cultural values.

NSW floodplain estuaries

The NSW analysis, led by Pia Weinberg from the University of Wollongong, includes the subtropical floodplain-dominated estuaries – essentially concentrating on the state's major estuaries while recognising that benefits would also accrue to south-east Queensland and to the Gippsland Lakes.

Sydney Rock Oyster (*Saccostrea glomerata*), Mullet and School Prawn (*Metapenaeus* spp.) are the three species used to calculate the potential cost-benefits. Total estimated productivity value increase for these selected species is at least $94 million a year. Other key commercial species not valued in terms of productivity improvements but likely to benefit from estuary repair include Eastern King Prawn, Yellowfin Bream (*Acanthopagrus australis*), Dusky Flathead (*Platycephalus fuscus*), Luderick (*Girella tricuspidata*), Mulloway, Garfish, eels and Whiting.

Other benefits from investment in NSW include: a reduction in, and severity of, disease or fish kills resulting from low-dissolved-oxygen, acidic blackwater; reduced methane emissions from deteriorating wetlands; improved carbon sequestration; and improved flood control.

Great Barrier Reef

Marcus Sheaves, from James Cook University, says the Great Barrier Reef is far more than just the coral reef – seagrasses, mangroves, salt marshes and brackish to freshwater wetlands are all essential parts of the reef ecology.

A lack of detailed history has made it difficult to separate habitat influences on the decline in fisheries productivity in the Great Barrier Reef region from other causes. Using catch data dating back to 1990, Tiger Prawns and Banana Prawns have been the species used in calculating improvements from habitat works, estimated to be $45 million a year. However, many other popular commercial recreation and commercial species including Barramundi (*Lates calcarifer*), Red Emperor (*Lutjanus sebae*) and Mangrove Jack (*Lutjanus argentimaculatus*) also have larval or juvenile phases inshore or nearshore and could be expected to benefit.

A REEF TO CALL HOME

The re-establishment of shellfish reefs to improve the productivity of fisheries has been identified as a priority for large embayments from Moreton Bay in south-east Queensland through to Victoria and Tasmania and across to Albany Harbour in south-west Western Australia.

Studies in several estuary systems worldwide have indicated that shellfish beds are a significant part of the food chain, provide important structural habitats for a large variety of invertebrate and fish species and provide increased protection from predators of juvenile fish.

Research in the US has demonstrated that once the water quality is improved, increasing the area of oyster beds can increase net fisheries production, and oyster reefs have been defined as 'essential fish habitat'. On the east coast of the US, one project in Chesapeake Bay used shell to rebuild the reef structures over 34 hectares. Native oysters repopulated these reefs, resulting in a 57-fold increase in the population to an astonishing 185 million oysters within five years.

In addition to their value as fish habitat, shellfish reefs provide nutrient cycling, water filtration, benthic–pelagic coupling, substrates for settlement of other invertebrate and algal species (the building blocks for biological reefs), sediment stabilisation and potentially even carbon sequestration.

Fisheries scientist Paul Hamer, from Fisheries Victoria, says recreational and professional fishers have long lamented the loss of shellfish beds in Port Phillip Bay. The reefs were seen as providing important feeding and nursery habitats for fish, particularly Snapper (*Pagrus auratus*).

Sedimentation, pollution and the introduction of exotic species, as well as periods of intense dredge fishing for shellfish, have all contributed to the decline or loss of shellfish reefs. Paul Hamer says a big issue with re-establishing shellfish beds is the lack of existing hard substrates, such as old shell beds, for the shellfish to attach to, as the historic shell beds were removed or buried.

Independently of the *Revitalising Australia's Estuaries* report, a pilot project has been developed for Port Phillip Bay to trial the use of various man-made substrates seeded with oyster and/or mussel spat, and planting out established adult oysters in re-establishing Native Oyster (*Ostrea angasi*) and mussel reefs.

Projects in the US have used oyster shells collected from restaurants to successfully reconstruct reef, with almost immediate improvements in fishery productivity. One project in Mobile Bay, Alabama, resulted in a 297 per cent increase in the Blue Crab population, a 108 per cent increase in Red Drum and 79 per cent increase in Flounder within five years.

Port Phillip Bay is well placed to implement such a similar fisheries rejuvenation project, which would benefit both professional and recreational fishers.

Other projects identified in *Revitalising Australia's Estuaries* include re-establishing Sydney Rock Oyster (*Saccostrea glomerata*) reefs in sheltered intertidal and subtidal zones in south-eastern Queensland, particularly around Moreton Bay, and rebuilding remnant reefs of Native Oysters in Georges Bay, Tasmania, and south-west Western Australia.

More information: Paul Hamer, 03 5258 0111, paul.hamer@depi.vic.gov.au

PHOTO: JOHN MERCER

Juvenile Native Oysters attached to grow-out ropes, Port Phillip Bay.

Marcus Sheaves says additional benefits from improvements in the Great Barrier Reef fisheries include increased productivity for recreational fishers across almost all popular species and supporting the Great Barrier Reef's \$4 to \$5 billion tourism industry. General improvements to estuarine habitats would flow through the reef biodiversity, including iconic species such as dugongs and turtles.

Protecting Indigenous cultures and communities in the region and greater carbon sequestration and protection of the Great Barrier Reef's World Heritage values have been identified as likely benefits.

Valuations

The project uses retail prices as the basis for fisheries values, but no non-market values or estimates of recreational fishing benefit have been included. "All dollar values are deliberately conservative. This project leaves it to others to speculate on dollar values for what this analysis regards as 'externalities', including the flow-on benefits to tackle shops, tourism, marine centres and so on," Colin Creighton says.

He identifies several types of repair opportunities across both public and private sectors, including:

- ponded pastures and the interface between grazing land and wetlands;
- bunds and weirs that may block tidal or flood flows;
- wetland drainage, floodgates and levee amendments to allow fish passage and restore wetland functions;
- infrastructure redesign to factor in floods, enhance tidal flows and fish passage;
- restoration of riparian landscapes; and
- re-establishment of estuary seagrasses and oyster and mussel shell beds.

The report identifies priority works in each state. Further planning and local approval processes will be needed on a case-by-case basis to ensure stakeholder agreement and to maximise return on investment in terms of improved fisheries productivity.

State priorities

In Western Australia, proposed works include: reconnected waterways in the Peel-Harvey catchment to the main estuary, especially the Serpentine River; identifying alternative outfalls for stormwater and drainage flows in the Leschenault region; and rehabilitation of the Point Souro foreshore. Reconnecting the upper Sabena River to the estuary system in the Vasse-Wonnerup region and the Marbelup Brook in the Torbay/Lake Powell system has also been suggested.

Proposed work in SA focuses on improving freshwater flows through the lower Murray River and Coorong systems, re-establishing seagrass beds now that there is better management of terrestrial run-off in Gulf St Vincent and Spencer Gulf, and providing fish passages and improving tidal flows through the south-east-coast lakes system including Lake Bonney SE and Lake George.

There are 24 modified and four highly modified estuaries in Victoria identified for works. Re-establishing oyster and mussel shellfish beds as the basic building block for multi-species fisheries is a priority for Port Phillip Bay and Western Port Bay. Re-establishing lateral connectivity in floodplain wetlands and salt marshes, rationalising drainage, restricting cattle access to salt marshes and reducing the risk of acidic anoxic water discharge from acid sulfate soils to estuaries have also been identified for works.


Native Oyster spat produced at the Queenscliff commercial shellfish hatchery.
PHOTO: JOHN MERCER

In Tasmania, re-creating multi-species fisheries in the D'entrecasteaux Channel and east coast estuaries based on re-establishing oyster beds has been identified as a priority. Re-establishing fish passage and tidal flows across all key estuaries, repairing salt marshes and sedge lands by restricting cattle and relocating drainage outflows have also been recommended, along with reducing siltation of the Tamar estuary and increasing flows to enhance the flushing of estuaries.

Significant works have already been undertaken in NSW to restore wetland processes and tidal flows, rebuilding fisheries productivity most notably in Hexham Swamp, Hunter River, Yarrahappini wetland, Macleay River, and Darawakh Swamp, Wallamba River. Much remains to be done. The many large floodplain systems in NSW provide multiple opportunities to increase fisheries productivity. Priority opportunities identified are:

- Tweed Estuary and Cudgen Lake, Richmond River and catchments including the Tuckean Swamp, Rocky Mouth Creek and Bungawalbin Creek wetlands;
- Clarence River system, including Everlasting Swamp, Shark Creek and Coldstream wetland processes, Wooloweyah Lagoon and Lower Estuary, and Broadwater;
- Bellingen and Nambucca catchments;
- Macleay catchment including Swan Pool, Belmore and Frogmore Swamps, and Clybucca wetland;
- Lake Innes;
- Manning catchment including the Cattai wetlands, Moto Swamp;
- Hunter River, including Woodberry Swamp, Purgatory Creek and Seaham Weir; and
- Shoalhaven floodplain wetlands.

Proposed works in Queensland outside the Great Barrier Reef catchment focus on re-establishing high-priority oyster reefs as the key to south-east Queensland fisheries productivity. Investment in repair is recommended for wetlands and nearshore seagrasses in the Great Sandy Strait, changes to boat mooring practices to reduce impacts on seagrass beds, and restoring fish passage wherever possible without compromising flood control and other instream developments such as irrigation water supply.

Of the 150 estuaries in the Northern Territory most are in near-pristine condition. Only three are 'modified' and only two are 'extensively modified'. The emphasis of any investment in habitat within the Northern Territory is aimed more at protection than repair. This includes support for further policy formulation to maximise habitat protection while recognising that further development will occur.

Natural Resources Management – where to?

a wander through northern rivers history with thoughts as to directions & what is next

Overall Goal –
more profitable and sustainable regional landscapes

This presentation -

1. northern rivers - reflection on settlement history
2. natural resources management – the stages so far
3. smarter land use – the potential next step?
4. floodplain management – an opportunity
5. policy environment – complex & challenging
6. where to? – some thoughts and criteria

Northern rivers pre-contact

* long huts – stable food resources
* dampened sinusoidal catchment hydrology
* oysters & other bivalves as in-stream purification systems
* ocean entrances – a myriad of sand spits and channels
* biodiversity- based nutrient cycling
* comparatively benign footprint

Scrub felling 1891

Part of a 3.5 ton sea mullet haul, Boambee Creek, near Coffs

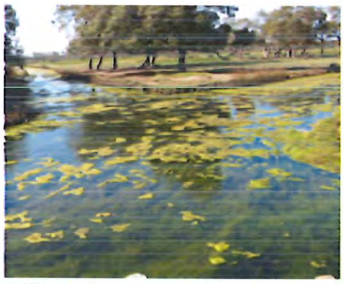
Early exploitation

* cedar getters [red gold] & river transport
* massive fish / waterfowl hunting available
* infrastructure around rivers, especially the floodplain levee
* major towns near tidal limit....and high flood heights before waters spread across floodplain
* coastal steamer shipping transport often unreliable & dangerous
* the lessons of Eliza Fraser's survival ignored
* efforts to conquer and tame this "foreign land" where the rain purportedly "followed the plough"

Tuckean Swamp drainage – abt. 1912

Settlers & European farming systems

* post and rail, kids, cream cans, pigs and pumpkins
* expectations of the "blockie" clearing scrub in this "new land"
* early Drainage Unions – e.g. Tuckean, Everlasting mirroring "the old country"
* training walls, wharves and consolidation
* then roads on the flood levees, ferries and towns turned around from wharves to face roads
* hard work, King and country
* "Big Scrub" – densest settled rural environment in Australia



Levees, drains, algae & de-oxygenation – how to start a "black water event" , a fish and prawn kill .....OR ...smarter land use.

Acquisition + repair now needed - Everlasting Swamp & Sportman's

Mechanization years

* post World War II – marked increase in mechanization
* tractors, often before cars – maize and dairy to sugar cane
* bridges replaced ferries, roads improved, rivers forgotten
* flood mitigation – started with levees around major towns and ended with excessive drainage / loss of forage / loss of creeks and tributaries
* Ballina Slipway and many "home-grown" trawlers – up to 72' such as *Seadreamer* – the new river/ ocean traffic
* ferry approaches + causeways constricting river channels + sediment from large scale clearing + sand from training walls all infilled estuaries

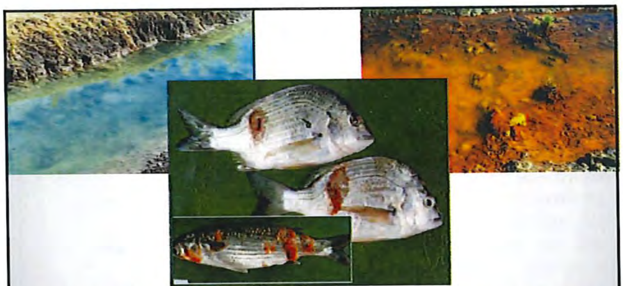
Lifestyle and alfresco living

* tourism, retirement and a services economy
* regional development focus on coasts and waterways
* towns turning back to the rivers & their amenity / landscape
* primary industries a lesser part of regional economies
* environmental credentials become essential
* Wallis Lake *hepatitis A* incident & Court Case
* fish kills, peaky flood events, coastal erosion, use conflicts
* more systemic regional responses essential – accelerated by an involved and sometimes litigious "new" community
* volatile regional economies needing a firm base

Clarence River – 2013 Flood Event:

Everything dead - benthic sampling from Grafton (below tidal limit) to ocean (some 90 river km downstream at Yamba).

This image – de-oxygenation and acidic effluent from drained wetlands killed all worms generally found in sediments



Repair the wetlands to minimize fish disease and oyster deaths

NRM phases
I - the early stirrings of an environmental consciousness articulated through action

* concern over excessive "flood mitigation"....which was actually land drainage where both grazers and fishers lost
* redspot and QX causing fishing industry decline
* heavy mineral sand mining & bitou-based rehabilitation
* establishment of coastal National Parks
* rainforest logging Vs conservation campaigns
* conflict-based decisions: e.g. Land and Environment Court rulings; SEPP 14 for wetland retention; many development approvals

LANDCARE

Bushcare

DUNE CARE

Dunes THE BACKBONE OF OUR BEACHES

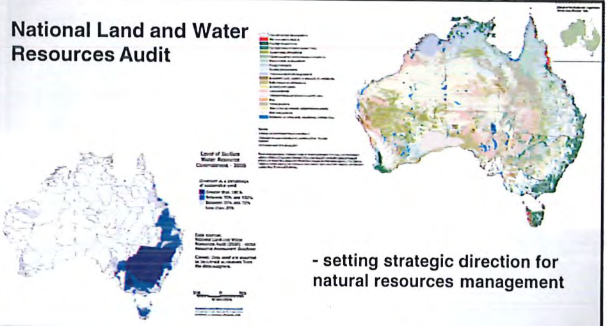
COASTCARE Community Program COAST ACTION

TCM

NRM phases
II – local partnerships

* conflict towards action - initially focus on producer groups and their practices - Landcare
* urban communities seek participation e.g. Dunecare and BushCare
* NSW Catchment Management Act formalises processes and seeks middle ground – "TCM"
* participation and media leads to gradual reduction in community polarisation
* simple concepts – e.g. "One Billion Trees"
* many "green" concerns start to become mainstream

National Land and Water Resources Audit



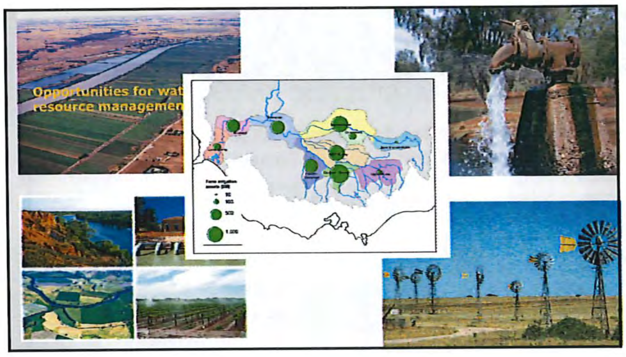
- setting strategic direction for natural resources management

NRM phases
III – Natural Heritage Trust Act & mainstreaming environment

* Howard Govt. philosophy – marginalize by capturing middle ground and make it a national agenda
* Ministers Hill and Anderson – Natural Heritage Trust Act
* Strong recognition + ongoing investment in "natural infrastructure"
* Minister Hill - EPBC Act & "biodiversity" entered lexicon
* natural resources protective legislation enhanced – vegetation + catchment management added to existing Water & Soil Acts

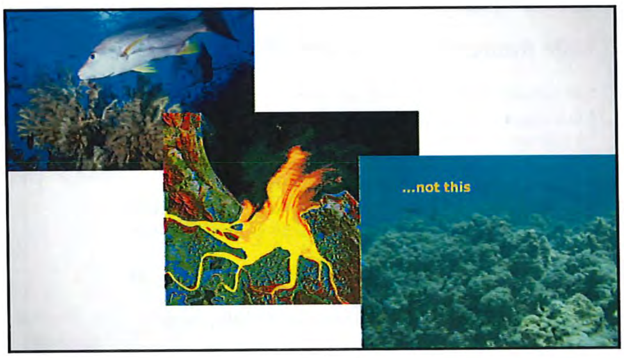
NRM phases
IV – Ambitious National Action Plans - e.g. for salinity & water quality

* $1.4B – to be spent in 20 priority catchments
* emphasis on managing existing land use + salt inception schemes the focus
* still not "working with nature" [McHarg] but rather a "war on salinity"
* public opposition to targeted approach – "every Landcare group should be allowed to plant trees"



NRM phases
V – Commodify water and foster demand management

* separate water title from land title
* set up tradable rights
* allocate water to environment
* foster community understanding of water costs / value
* implement water use efficiency on farm, industry and urban
* privatize or at least corporatize water supply and management
* water supply and use – part of smart business practices



NRM phases
VI – incentives-based approaches e.g. Reef Rescue

* strong business case orientation
* win-win solutions and partnership approach
* comparatively easy as a National icon
* limited flow-ons south of the GBR
* similar smaller initiatives developed
* all focus on land use practice
* all avoid the issues of inappropriate land use

Mangrove Jack – a tropical species - caught at Eden

NRM phases
VII – climate change - our worst ever public policy debate

* doom and gloom, fear-mongering and "belief" ..... should be evidence based
* value-laden debate...... should be simple messages of energy use efficiency and minimizing pollution
* negative "campaigns" ......polarise broader community
* Govt response - create an economic market around an externality and a market failure??
* politicised and polarised + lacked leadership vision

IMAS translatingnatureintoknowledge

INSTITUTE FOR MARINE AND ANTARCTIC STUDIES
www.imas.utas.edu.au

Preparing fisheries for climate change: identifying adaptation options for four key fisheries in SE Australia

Team: Gretta Pecl & Tim Ward (co-PI's)
Dallas D'Silva, Caleb Gardner, Philip Gibbs, Andrew Goulstone, Alistair Hobday, Greg Jenkins, Stephen Mayfield & many others

Victoria Department of Primary Industries · NSW Industry & Investment · National Research FLAGSHIPS · CSIRO · Australian Government Department of Agriculture, Fisheries and Forestry · Government of South Australia · SARDI · UTAS · Tasmania

IMAS - in partnership with the Tasmanian State Government

NRM phases
VII – *"the nrm industry in decline"*

* since when was it "an industry"?
* perhaps its time for a hard thinking honest evaluation of what we have / have not achieved
* many, many positives....but also much wasted opportunity and resources
* reflection, re-thinking and criteria for going forward is essential

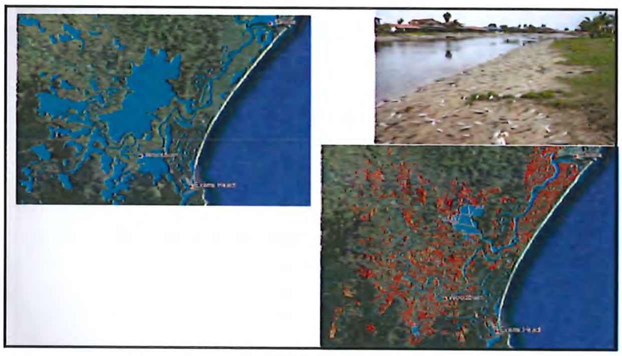
NRM futures – some draft criteria

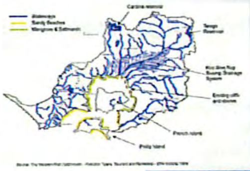
* solutions orientated and win-win
* business case driven and preferably program scale
* evidence-based & clear return on investment / targets
* addressing the "hard" issues
* reduced and preferably set transaction costs
* continuum from policy & regulation to incentives & works to <u>useful</u> monitoring, research & innovation & communication
* local to regional leadership, vision and strong, well-balanced community champions
* part of core business and regional development

Revitalising Floodplain Systems

-multiple benefits if we can meet the challenges of turning the tide on past mistakes.....

Estuaries & wetlands repair – key

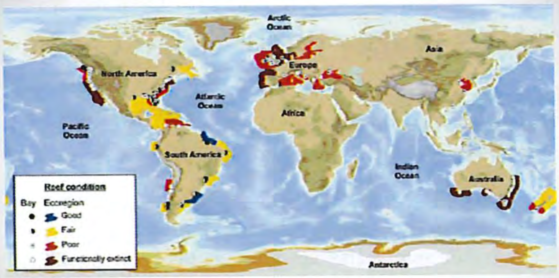



Westernport, Vic

Drive from Melb & now difficult to comprehend what we have lost


Big Swamp, Manning – pollution could be fish production – acquisition & repair needed



Within Estuary Repair - If oyster and mussel reefs were the Great Barrier Reef…. *functionally extinct*

Oyster and mussel reefs –

within estuary multi-dimensional habitat and purification systems

e.g. basis to re-establish Port Phillip snapper fishery

Filtering capacity of a US horse mussel

Re-establishing oyster and mussel reefs will provide 3 dimensional:
* nursery – crustacean & fish spp.
* fish habitat [e.g. snapper]
* water purification
* risk management for extreme event catchment runoff & aquaculture industry

Estuaries & wetlands repair

– key to Australia's productivity with multiple benefits

*** Jobs**
*** Lifestyle**
*** Biodiversity**
*** Food security**
*** Balance of trade**
*** Health**

But……how do we gain investment?

The state of play

1. For Australia' s estuary dependent fisheries our resource has markedly declined
2. Many of us have already worked hard to protect fisheries habitat and to repair our estuaries - much excellent work and research to build on
3. However to make major gains in productivity we need major leadership, strong partnerships & targeted investment
4. To gain political and community support for major investment in estuary and fisheries habitat repair we need clear and unambiguous benefits well exceeding the costs.
5. *Revitalising Australia's Estuaries* provides an inventory of high priority achievable repair opportunities and the business case for investment

The *Revitalising Australia's Estuaries* proposal:

❑ Planning works -	$21M	[6%]
❑ Works -	$238M	[68%]
❑ Monitoring -	$24.5M	[7%]
❑ Reporting-	$10.5M	[3%]
❑ Communication & Legacy	$17.5M	[5%]
❑ Policy development	$17.5M	[5%]
❑ Research & Knowledge	$21M	[6%]

Total of $350M with break-even on investment estimated at less than 5 years using just a selection of increased commercial catch rates.

Thematic Repair Priorities

* Restoring connectivity and fish passage – barrages, blocks, inadequate culverts, causeways
* Restoring estuary processes – especially tidal and freshwater flows and fluxes, ph and oxygenation
* Repairing drained floodplain wetlands – removing or manipulating barrages to allow tidal water and wetland recovery and reshaping landforms to remove drains and levees, especially for acid sulphate
* Re-establishing mussel and oyster reefs - key within-estuary nursery through to adult fishery habitat as well as performing a water quality improvement function
* Re-establishing seagrasses – replanting of initial re-colonizers especially in the SA gulfs and the provision of seagrass friendly moorings

$$$$$ profit - the Business Case

Selected fisheries :

* A single regional fishery, Murray + Coorong,
  Mulloway, Black Bream, Greenback Flounder and Yelloweye Mullet.
* A state, New South Wales floodplain estuaries
  Sydney Rock Oyster, School Prawn and Mullet
* An iconic region, the Great Barrier Reef salt marshes
  Banana Prawns and Tiger Prawns.

Coorong and Murray Mouth

* Commercial fishery worth $5.7 million pa – included Mulloway, Yelloweye Mullet, Black Bream, Greenback Flounder
* Productivity improvements 20%: $260,000 pa
* Break-even point: less than 7 years


Photo: theaustralian.com.au


Photo: coorongfishery.com

NSW floodplain estuaries

* Selected species -Sydney Rock Oyster, Mullet, School Prawn
* Productivity value increase at least $94M pa
* Break-even point - less than 3 years

Images courtesy of DPI NSW



Great Barrier Reef – salt marshes & connectivity

* Selected species - Banana & Tiger Prawns
* Productivity value increase at least $45M pa
* Break-even point - less than 2 years

What does repair look like?
e.g. Wallis Lake

Repair – e.g. Little Broadwater, Clarence

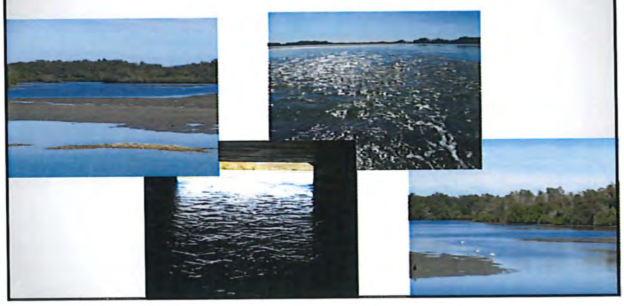
Floodgate and drain removal Clarence floodplain **– soil carbon + biodiversity + productivity + fishery + water quality**

⇦ Business as usual is drained poorly productive wetlands.....

Tidal flow partial repair e.g. Shallow Channel, Clarence

- **2 box culverts**
- **Green slime and mud to sand spits, high tidal flow and fast food zone**

Shallow Channel, Clarence



So what…or where to... for northern NSW?

Challenging….but then a re-think may yield opportunities:

* limited Aust. Govt. $ in environmental repair and many worthy opportunities

* likewise limited $ and many competing needs in States

* infrastructure is a major focus for Aust. Govt.

* food security and productivity and human health/ lifestyle are also Aust. Govt. priorities

Some suggested criteria for investment proposals

* System wide – think economic + social + biophysical 'catchments'

* Multi-objective – e.g.
  + improved land, water and air transport infrastructure
  + enhanced flood management
  + fishery productivity
  + agricultural productivity
  + secondary and services industries
  + lifestyle amenity

– all with long term employment and enhanced regional economies the goal

Some suggested criteria for investment proposals [cont.]

* Competitive and cohesive –
  + all key industry and community partners
  + well articulated return on investment
  + clear co-investment streams
  + pragmatic & achievable

* Innovative in outcome, smart in policy –
  + clear community benefits
  + innovative revenue systems such as Trusts [that avoid the need for ongoing investment]
  + smarter streamlined regulatory environment and policies

........but avoid such as hypothecated taxes and trying to price externalities

Some suggested criteria for investment proposals [cont.]

* Program orientated as a total package –
  + planning
  + works
  + R&D and innovation
  + policy enhancement
  + monitoring
  + reporting
  + communication and involvement / ownership

* Clear in outputs and measurable in time bound targets –
  + multi-dimensional across social – economic - biophysical
  + simple and readily understood
  + achievable and if needed a phased approach

In brief, initiatives need to:

* focus to demonstrate the vision
* align R&D and works to ensure success
* monitor to demonstrate delivery to proposed ROI
* collaborate as exemplar public-private partnerships
* promote to position for ongoing $ investment
* span the regional economy and community

Preparing fisheries for climate change

Number 6

MODELLING THE FUTURE OF AUSTRALIA'S OCEANS

The world is changing and southeastern Australia is changing more rapidly than most. What will the future hold for the region? The Atlantis computer model was used to explore alternative possible futures.

While some futures show significant declines and dreary prospects many more show that the system is robust and that sustainable marine fisheries and aquaculture are possible.

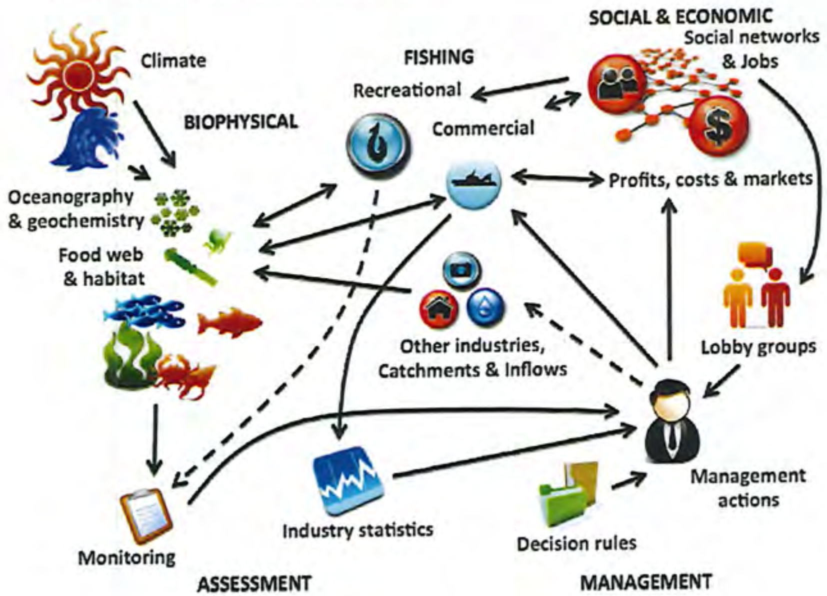
As long as communities, markets and management remains flexible the region can adapt to any environmental change. It will be important however to take an integrated approach across all marine and coastal industries so that cumulative pressure can be kept within acceptable

The Earth's marine and coastal systems are changing. For industries, such as fisheries and aquaculture, and societies who rely on marine resources there is a need to adapt, to move away from some activities and make the most of new opportunities.

Southeast Australia is a global hotspot of environmental change, but it is also a hotspot for marine production, human use and population. To help Australia's southeastern comunities and industries remain sustainable and resilient a multiyear, multi-institutional effort (bringing together universities, CSIRO, industry, managers and public) was undertaken as a first step in understanding and assessing risks and finding better future outcomes.

Part of this work used sophisticated computer models to synthesise all the available information and explore what the alternative futures many hold. The modelling identified a range of potential barriers to adaptation, some biological, some based in human behaviour, markets and management regulations. These can act in isolation or in combination, with the human barriers often presenting greater challenges than potential biological changes.

A model for exploring alternative futures



The models used to explore the possible futures (using the Atlantis modelling software) include all parts of the southeastern Australian marine system: environment, habitats, food webs, industries, markets, communities and management.

Ecosystems can cope to a point

Current carbon dioxide levels in the atmosphere are about 400ppm (they vary a little bit with location and season), having risen from about 278ppm over the last 200 years. The modelling indicated that up to a point (at around 550+ ppm, which could be reached by mid-century) ecological systems have sufficient adaptive capacity to ensure that the structure and function of Australia's southeastern marine ecosystem persist. Many components of the shelf-to-offshore ecosystems may shift in abundance or spatial distribution, but the shift's won't be large enough to see a complete reshaping of the general form of the ecosystems. This is because biological adaptation (via acclimation or evolution) is sufficiently rapid that by 2070 the ecological groups have proven to be fairly resilient to the magnitude of change seen. This is not the case if emissions remain high and carbon dioxide levels exceed 700ppm (again possible by mid-century), where ecological rates of change, especially for demersal species, may be overwhelmed. In this case species rely on spatial range shifts as the major coping mechanism - ultimately potentially running out of shelf habitat in the 2070s.

The larger the ecological changes the greater the required social, market and industry adaptation.

The shape of potential futures

KEY (Best possible = blue; Worst case = grey)

- ↓ Decreases > 20%
- ↕ < 20% change (no real change)
- ↑ Increases > 20%
- ⇈ More than double
- ✶ Highly Variable
- S Spatially variable, inshore response opposite to offshore (overall result shown)

INDICATOR	Low (<450 ppm CO_2) best	Low worst	Medium (450-700 ppm CO_2) best	Medium worst	High (>700 ppm CO_2) best	High worst	High & No acclimation
Average sea surface temperature	+ 1 °C		+ 1.5 °C		+ 2 °C		+ 2 °C
Ocean acidity	+ 13%		+ 27%		+ 305%		+ 305%
Primary Production	↑	↑	↑	↑	↑	↑	↑
	↑	↕	↕	↕	↑	↓	↓
Habitats	⇈	⇈ S	⇈	↑	↑	↓	↓
Forge (prey) fish	↑	↓	↕	↕	↑	↕ S	↓
Large predatory fish	↑	↓	↕	↓	⇈	↓	↓
Bottom dwelling fish	↑	↕	↑	↕	⇈	⇈	↕
Marine mammals & seabirds	⇈	⇈	↑	↑	⇈	↑	↑
	↕	↕	↕	↕	↓	↓	↓
Sharks	↕	↓	↓	↓	↓	↓	↓
Oysters & mussels	↑	↓	↕	↕	↕	↓	↓
Urchins & abalone	✶	✶	↕	↓	✶	✶	↓
Lobster	↕	⇈	↕	⇈	↕	⇈	⇈
Squid	↕	↓	↕	↓	↕	↓	↓
Stock & ecosystem health (proportion of species considered vulnerable)	↓	⇈	↓	⇈	↓	⇈	↑
Biodiversity	↕	↓	↕	↓	↑	↓	↓
Landings (catch) of low value species	⇈	↕	↑	↓	⇈	↑	↕
Landings (catch) of high value species	↑	⇈	↑	⇈	↑	↑	↕
Gross value of fisheries (per unit effort)	↕	⇈	↓	⇈	↓	↓	↑
	⇈	⇈	⇈	⇈	⇈	⇈	↕
Catch by new fisheries (initiated on new species post 2010)	↑	↓	↑	↓	↑	↓	↓

General direction of change (compared to 2010) for different parts of the system - ecological, economic and social - under different emissions scenarios (the CO_2 value is the atmospheric carbon dioxide levels in 2060 in parts per million). All the simulations included ocean warming & acidifcation, an expanding Australian population and multiple industries using the coastal zones (e.g. fisheries, shipping, port developments). Best possible management was integrated management across all industries. Worst case was when there was little or no effective management in any industry and large cumulative impacts. No acclimation indicates the system outcome if species are completely unable to adjust to new conditions.

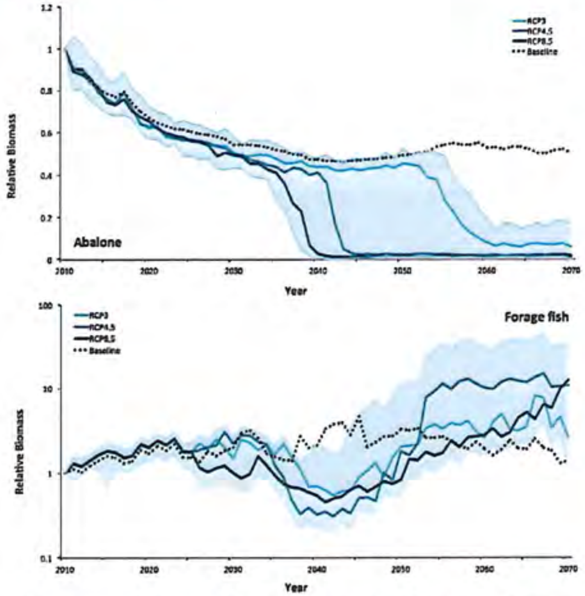
Changes will be longlived and complicated

Ecosystems are complex, with change in the abundance of individual species likely following complicated trajectories rather than simple increases or declines. Range extending species, like Pink Snapper in Tasmania, will increase strongly before competition with resident species (e.g. flathead) will damp and stabilise the growing population. As the degree of human pressure on the ecosystem grows through time, processes that initially acted in opposition (e.g. ocean warming and acidification) eventually switch to act synergistically, further enhancing the level of change. Ecosystems are never static, but the coming change is likely to be much more rapid than at any other point in the last 55 million years and will continue for many decades or centuries (due to the length of time it takes for some of the physical, chemical and ecological interactions to play out).

The novel form of these future ecosystems means that their exact content and function is uncertain, at their most extreme they could be quite different to what is observed today. Delaying decisions while waiting for more information may provde a perception of stability in the short term, but uncertainty will never be expunged and the modelling shows that in the long term an adaptive governance system (that acts and updates or changes regulations as new information arises) performs more strongly.

The human parts of the ecosystem - the markets, regulations and industries - will need to change along with the rest of the system. To do this effectively will require good information, sustained observing of the marine enviroment is required to detect and attribute current and future changes. The complex nature of the ecosystems being monitored means that observations will need to cover many of the key facets of the ecosystem: temperature, salinity, pH, oxygen content, the abundance of primary producers, the species targetted by fisheries, habitat forming species, top predators (like sharks, seals, whales and birds), fisheries landings (catches) and discards, prices and employment statistics. As the system changes, changes in the monitoring scheme may also be needed for it to remain informative and representative of the new system state and structure.

Change through time



Examples of biomass trajectories through time - relative to the state in 2010 - for abalone and forage fish (small pelagic fish). Baseline is if 2010 conditions continued indefinitely (shown for reference purposes) and the RCP scenarios are the IPCC emissions scenarios (RCP3 = low emissions, RCP4.5 = medium emissions, RCP8.5 = high emissions). The lighter shaded area is the total range of outcomes across all model simulations.

Six barriers to adaptation have been fidentified:

1. **Biological & ecological:** shifts in productivity, abundance and spatial distribution may reshape (or disrupt) ecosystems.

2. **Behavioural:** depending on their personality & available resources not all industry members have the same flexibilityto respond & adapt.

3. **Governance & regulation:** can inhibit adaptation if decisions are delayed, inflexible or promote actions leading to economic or social hardship.

4. **Economics & markets:** may focus on short term results (shaped by societal desires) & lead to maladaptive behaviour in the long term

5. **Technological:** existing technology shapes behaviour, it does not guarantee adaptive responses.

6. **Knowledge:** understanding is required to make wise decisions, insufficient or poor information can stall adaptation.

Atlantis (the model used to explore futures for southeastern Australia), suggests that all six types of potential barriers to adaptation

Effective management

Even without extreme change any declines or shifts in species distributions will raise challenges for management. Current often state-based jurisdictions present multiple access, allocation and legal quandries when stocks straddle jurisdictions or moves between them. While aquaculture will not have to grapple with shifting stocks it will face analogous issues around gaining access to suitable locations (as environmental drivers shift and previously used locations become less suitable). Given the already crowded nature of southeastern marine waters and the development of new industries, such as energy and aggregate mining, there will be lots of competition for any available space.

Aquaculture may need to change the species farmed (salmon for instance may not remain viable in the long term) and the fishing industry may need to change where they fish and what they target. This may not be easy and will depend on their circumstances, their understanding of the situation, their perception of risk and their social and institutional context. If markets do not exost for new species, or society acts harshly to changes because they do not realise why it is needed, then necessary change may not happen. This can lead to economic hardship and degradation of the ecosystem.

Flexible and integrated management can avoid hardship by allowing matching spatial shifts in human use or by allowing more flexible targeting. To do this successfully, management will need to show more integration across Australia, across industries, down catchments and out to sea and will need to develop frameworks that deal with range extensions, contractions or regime shifts.

The modelling indicated that reduction in spatial management is a universally poor management option, while management arrangements where management jurisdiction matches species extent were identified as an effective means of retaining sustainability and cost effective management as species distributions shift. Integrated management (across jurisdictions and industries) was even more effective, balancing performance across conservation, industry and economic objectives.

Allowing the flow of information amongst agencies is a good first step, as is the use of a mix of management rules (e.g. quotas, gear restrictions and spatial management) within fisheries. However, this needs to progress to a set of agreed common approaches, objectives and integration across fisheries and from there to integrated multiple use management across all users of the marine and coastal space. Each accounting for the influences the others have on the shared space.

A lack of agreement over objectives for the system as a whole means there will be tradeoffs and compromises. In addition, some of the required regulatory and industry shifts that would need to accompany such management shifts are currently unpalatable to at least some segments of Australian society (e.g. the influence of recreational fishing on marine ecosystems needs to be more clearly recognised). However, changes in behaviour, market practices and regulation are needed to stay apace with change more broadly. Ultimately the sequence of management changes required is no regret, with each step beneficial in its own right.

The modelling shows that following this path presents many advantages over remaining with single industry focused management or letting regulations or enforcement degrade. Effective management of fisheries, aquaculture and other marine industries and coastal uses is an effective means of providing ecosystems with an improved capacity for adaptation.

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www.csiro.au/seaview
www.redmap.org.au
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Marine Australia

ADAPTING TO A CHANGING CLIMATE | Overview fact sheet

Australia's oceans, their physical characteristics, marine biodiversity and fisheries are already experiencing and responding to a changing and more variable climate. This is occurring at a far more rapid rate than change on land.

Adapting to our changing climate is best undertaken as part of an overall strategy to improve Australia's marine biodiversity and fisheries management. Climate change is one of many issues. Others for fisheries include input costs, market conditions and price for product, labour availability, access to fishing grounds and resource sharing, changing management arrangements and reduced productivity in stocks due to losses in habitat and water quality. Working across all of these issues rather than focusing just on climate change will ensure we can build upon and profit from the wealth of goods and services provided by our marine environment. Working across all the issues recognises all the changes, opportunities and threats for marine Australia.

Priority areas for action

1. Improved forecasting

Accurate marine forecasting is essential to inform ship movements, defence, fisheries, oil and natural gas extraction, as well as any other decisions about using the ocean. Forecasting will become even more important as ocean conditions become more variable due to a changing climate. Investment through the Bureau of Meteorology linked to the data sets being collated by the Integrated Marine Observing System (IMOS) could improve marine forecasting, lead to developing user-specific modules and generally enhance information accessibility and applicability to all marine users. With ocean conditions influencing much of our terrestrial weather patterns, flow-on benefits to land weather services would also be substantial.

2. Enhanced stock assessment

Smarter and real-time stock assessment and population predictions will foster a more profitable and sustainable fishing sector. Fishing activities can become more targeted and profitable, achieving similar or increased catches with less effort, there will be increased certainty for fishers and we will be better able to fine tune management interventions to ensure sustainability. Underpining enhanced stock assessment, we will need to develop cheaper monitoring systems, better analysis of data and stronger links between monitoring and management actions. A changing more variable climate will especially affect the total population of short lived species such as annual stocks of prawns and three year stocks such as lobsters and Barramundi. The Northern Prawn fishery and the Western Rock Lobster fishery already provide excellent examples of the benefits of this approach to fisheries management and profitability.

3. Total population systems

Under the influence of a changing and more variable climate, species such as Snapper, Spanner Crab, Eastern and Southern Rock Lobsters are well known for changing range and total stock numbers. Their recruitment, growth, range and spawning processes all link to the environment of our oceans and have no regard for state boundaries or fishing zones. Yet we manage stocks based on state boundaries. Likewise seabirds and marine mammals are not constrained to particular jurisdictions. Moving to whole-of-stock/population monitoring and management, rather than jurisdiction management, is one of the next major steps in both fisheries management and species conservation.

Related to this is the need to encourage more flexible conservation and fisheries management, to ensure healthy biodiverse marine environments and profitable fishing industries. Rigid boundaries for marine parks or for fisheries entitlements may have limited relevance when stocks are fluctuating and moving in range.

4. Fostering industry development

While most of Australia's wild fisheries are already managed to ensure sustainable economic yield, there are opportunities for increased productivity and profitability as well as improved protection and conservation. Some of these opportunities include:

- re-establishing oyster and mussel reefs in sheltered inshore environments such as Port Phillip, Moreton Bay and D'Encastreau Channel will help assimilate nutrients as well as providing massive increases in habitat available for species such as Snapper;
- in northern Australia, prediction models are needed to inform decisions about where to located aquaculture precincts. For example, areas off the northern coastline are potentially suitable for offshore sea cage aquaculture;
- aquaculture development and the protection of existing habitat for wild fisheries – commercial, recreational and indigenous can be best explored as part of the Government's northern Australia development strategy.

5. Building resilience to extreme shock events and increasing productivity

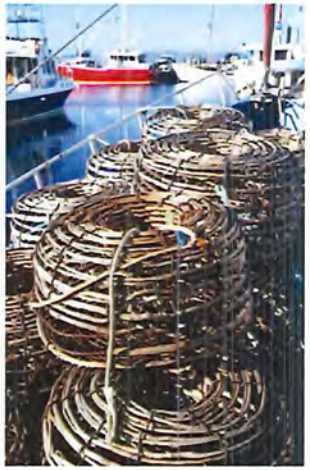
Re-designing catchment landscapes and repairing key elements of fisheries and biodiversity productivity is essential for productivity. The damage caused to our fisheries by past mistakes in land use and water quality is well documented. A changing climate adds to the imperative for repair so that we can ensure our inshore resources are more resiliant to more frequent extreme flooding and drought events. Re-establishing connectivity, seagrasses, salt marshes, tidal flows, freshwater flows, floodplain wetlands and water quality will all foster healthier, more resilient ecosystems and ensure our marine environments are better able to cope with extreme events.

6. Sustainable environmental & economic yield

Loss of habitat and declining water quality are often to blame in the loss of ecosystem productivity. This affects marine mammals and seabird populations as well as fisheries. While much of our management has been transitioning to Sustainable Economic Yield [SEY], we now need to move to Sustainable Economic and Environmental Yield [SEEY]. Stock productivity rather than catch per unit effort should be used as the primary measure of successful management. This will become even more important over time as Australia experiences increasing climate variability.

7. Building smarter governance structures

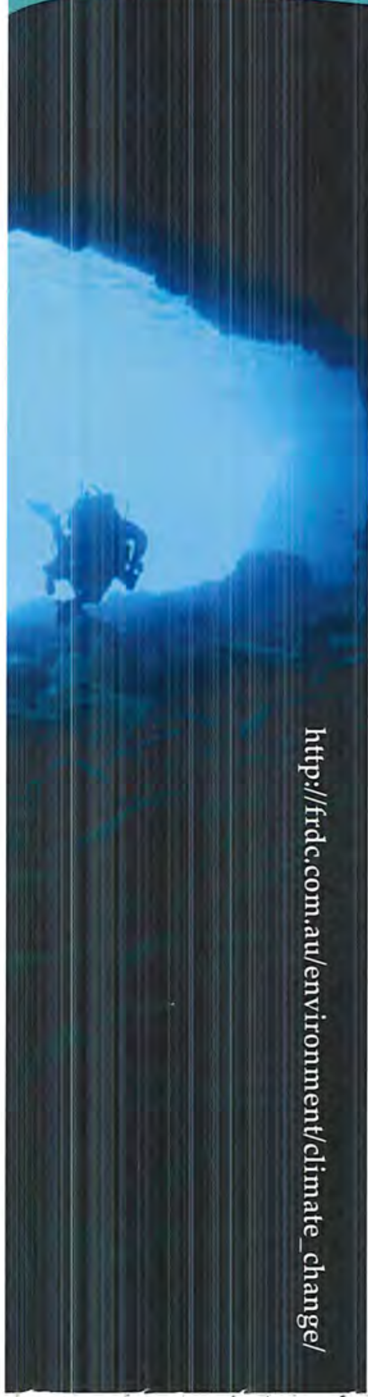
Much of our governance focusses on single objectives, one agency may be unaware or may not take into account what another agency is doing. Likewise a changing climate is just one of many stressors that need to be accomodated by management. There is also not yet a coherent funding model for managing our marine and inshore ecosystems. A Trust process is already proposed for the Great Barrier Reef. Trusts and other structures that lead to a joint focus and agreement across management bodies would ensure Australia is better equipped to manage changing environments, including the changes expected to occur through a changing climate. Certainly this is the overseas experience e.g. Georgia Basin (Washington state, US) or in the Puget Sound (Canada trans-boundary region).



8. Contributing to smarter energy use and to climate mitigation

Reducing the carbon footprint of marine users – Fuel is a major part of the input costs for all vessels whether involved in wild fisheries, marine park or fisheries enforcement. It is also a major cost in undertaking marine research. In other maritime nations such as New Zealand, specific initiatives have targeted fuel efficiency. This includes incentives for installing fuel flow meters, training in smarter boat use, systems for sea 'mooring' on the fishery, more fuel efficient gear such as improvements to otter boards, and designs that further reduce by-catch. An initiative targeted on more efficient marine practices would provide multiple benefits including increased profitability, reduced carbon footprint and less impact on the marine environment.

Energy efficient & carbon-smart aquaculture – Energy is a major cost input to virtually all aquaculture systems. As the price of energy increases so do aquaculture industry costs, while profit margins decrease. Technical support to implement energy-efficient changes to aquaculture operations would greatly assist the Australian aquaculture industry. Activities could include energy audits and developing business case assessments to evaluate the profitability of investing in more energy efficient equipment.



More research is needed to devise multi-faceted aquaculture systems that deliver carbon sequestration, energy generation and food production. A good example of such a system is macro-algae linked to prawn farms for protein production as a source for both agricultural and aquaculture feeds.

Blue Carbon - There are substantial opportunities for coastal wetlands, seagrasses, mangroves and salt marshes to contribute to a carbon economy as they sequester over 39% of Australia's carbon even though they only cover less than 1% of the landscape. These marine environments need to become part of Australia's National Carbon Accounts. Investment for carbon mitigation would have the flow on benefits of improved fisheries habitat, flood control, and infrastructure as well as increasing biodiversity.

9. Concluding comments

The FRDC-led program and its investments in research leaves the very important legacy of providing tools for including more and more climate considerations into marine policy and management. Most of the FRDC investment will now be focused on including climate as an integral part of the continuous challenge to improve Australia's marine policy and management. Certainly there may be occasional climate-specific investments. Nevertheless, from an adoption perspective the challenge is to include the implications of climate, climate change and climate adaptation within the broader area of policy formulation and management of Australia's marine biodiversity and fisheries.

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South East Australian Program

Preparing fisheries for climate change

ABALONE fact sheet

Temperatures recorded off the east coast of Tasmania over the last 70 years have shown that this region is warming at 3.8 times the global average.

Over the next century, the marine systems of south-east Australia are expected to continue exhibiting some of the largest climate-driven changes in the Southern Hemisphere, with substantial changes to ecosystems. The subsequent flow-on effects to communities and businesses will depend, in part, on how well fishing industries and resource managers can adapt to these challenges.

Abalone was one of four case-study fisheries selected to identify likely effects of climate change and highlighting how fishery assessment and management frameworks could be adjusted for better consider climate change.

The fishery

Abalone resources support important commercial and recreational fisheries across Western Australia (WA), South Australia (SA), Victoria (Vic), New South Wales (NSW) and Tasmania (Tas).

Two of the most commercially important species are blacklip abalone (Haliotis rubra) and greenlip abalone (H. laevigata). These species dominate the catches, accounting for 82%, and 15% of wild abalone production in Australia, respectively.

Blacklip abalone are harvested commercially across all four south-eastern states (NSW, VIC, TAS, and SA), while greenlip abalone are harvested in VIC, TAS, SA and WA.

Abalone is the second most valuable wild fisheries product in Australia after rock lobster. The total annual catch is approximately 4500 tonnes with an estimated annual gross commercial value of AUS$200 million.

Fishing involves divers hand-harvesting the product from reefs at water depths from 1 to 40m. The fisheries are managed separately within each jurisdiction using tools comprising both input (e.g. limited entry to the fishery) and output (e.g. minimum legal sizes, total allowable commercial catches (TACCs)). Collectively these have been largely successful with Australian abalone production generally sustainable in comparison to fisheries for these molluscs elsewhere.

About the case study

An extensive review of the literature identified that abalone have reduced ability to cope with warm water temperatures and increased acidification. Blacklip abalone have a lower preferred water temperature and a lower thermal tolerance than greenlip.

This project was the first to examine environmental drivers of fishery production across the range of the Australian abalone fisheries and across all available environmental data including sea surface temperatures, salinity, tidal flow and swell.

Relationships between environmental factors and fishery production were examined at spatial scales consistent with abalone stock structure.

How changes in the physical environment may affect abalone production

Determining the extent to which climate change may influence Australian abalone stocks was challenging. Abalone stocks and fisheries are likely to be influenced by three aspects of climate change:

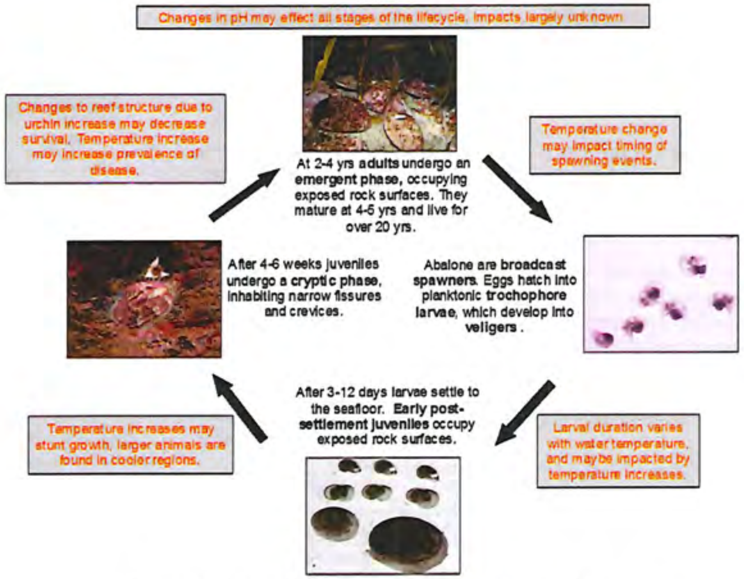
(1) gradual increases in water temperature and ocean acidification;

(2) increased frequency and magnitude of extreme events (e.g. marine heat waves); and

(3) changes in the distribution, abundance or activity of competitors and predators (e.g. range extension of the long-spined sea urchin *Centrostephanus rodgersii*). Collectively these are likely to result in reduced productivity and catches of abalone.

The future productivity of abalone fisheries in the south-east will be impacted by climate change through a combination of slower growth rates and increased frequency of mortality events.

- At warmer summer temperatures the size of abalone at reproductive maturity and the maximum sizes obtained were smaller than those at cooler summer water temperatures.
- For blacklip, warmer water temperatures during summer were typically associated with lower blacklip catches (however, there were exceptions to this pattern).
- Relationships between greenlip catches and the oceanographic variables considered in this study were less clear than those for blacklip, but the general overall trend was for larger greenlip catches to have been obtained from those areas with (1) slower tidal flow rates; and (2) relatively stable water temperatures with a low incidence of more 'extreme' temperatures, eg absence of very high or very cold summers or very cold winter temperatures.



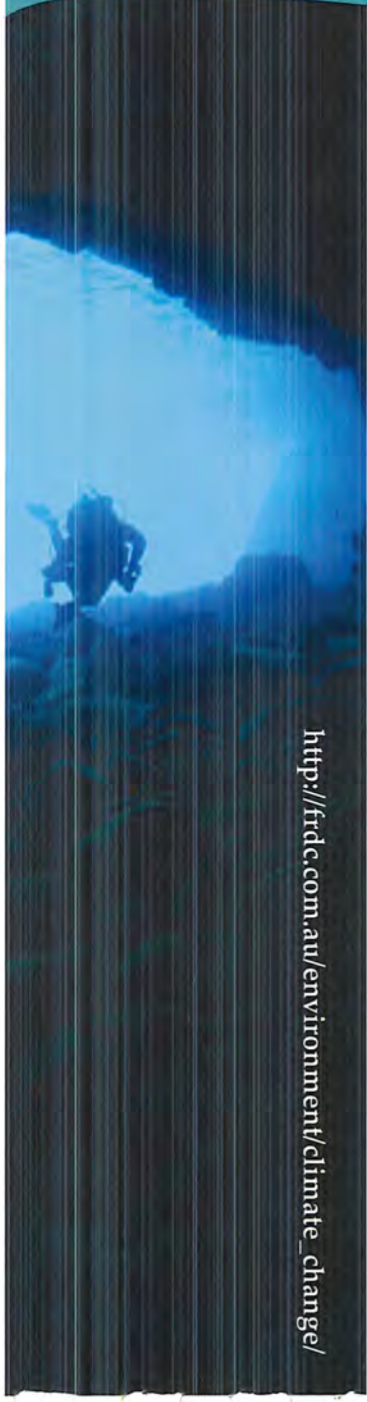
Summary of life cycle of Haliotis sp., and points of exposure to relevant climate change drivers or known impacts.

Vulnerability of assessment and management systems to climate change

Existing management systems appear robust to climate change, even though the impacts of climate change on the abalone stocks is unlikely to be uniform in time or space. This is because (1) current assessments in all jurisdictions are undertaken at appropriate spatial scales and (2) it is likely that the current measures of stock status (i.e. CPUE as an index of relative abundance, size structure of the commercial catch, density estimates from fishery-independent surveys) will remain suitable.

New indices (e.g. spatial performance indicators), may provide valuable additional insights and provide capacity to map fine-scale changes in productivity.

Reference points and decision rules for the Australian abalone fisheries are reviewed on an ongoing basis and the potential impacts of climate change are a component of this process.



Knowledge requirements into the future

To maximise our understanding of any future changes in the abalone fishery we need:

- *in situ* water temperature monitoring
- periodic sampling of abalone to monitor changes in growth-rates, size at maturity and abundance
- harvest strategies that are tested using management strategy evaluation (MSE) to ensure responsiveness to changes in stock abundance and productivity

Ensuring that the fisheries of south-east Australia adapt effectively to climate change will require robust scientific understanding and the development of management systems that will allow negative impacts to be mitigated and opportunities that arise to be seized.

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BLUE GRENADIER fact sheet

Ocean temperatures observed around south-east Australia show warming significantly above the global average, including temperatures recorded off the east coast of Tasmania over the last 70 years demonstrating warming at 3.8 times the global average.

Over the next century, the marine systems of south-east Australia are expected to continue exhibiting some of the largest climate-driven changes in the Southern Hemisphere, with substantial changes to ecosystems. The subsequent flow-on effects to communities and businesses will depend, in part, on how well fishing industries and resource managers can adapt to these challenges.

Blue grenadier was one of four case-study fisheries selected to identify likely effects of climate change and highlight how fishery assessment and management frameworks could be adjusted to better consider climate change.

The fishery

Blue grenadier (*Macruronus novaezelandiae*) support the most valuable commercial fin-fish fishery in the Southern and Eastern Scalefish and Shark Fishery. The landed fishery market value is approximately $12–14 million Australian dollars. The Australian blue grenadier fishery is a solely Commonwealth managed fishery and the Australian Fishery Management Authority (AFMA) is responsible for its management (assessment and setting of the total allowable catch or TAC).

Blue grenadier are found from southern New South Wales around southern Australia to Western Australia, including around the coast of Tasmania. Most of the catch is taken from around western Tasmania with smaller catches off eastern Tasmania and eastern Bass Strait.

Blue grenadier are typically targeted along the shelf slope at depths between 300 and 600 m, but can occur to depths of at least 1000 m. The species is caught by demersal trawling and the annual TAC ranged between approximately 4300 to 5200 tonnes between 2008 and 2012, but was as large as 10,000 t between 1994 and 2002.

The fishery is divided into a smaller summer (non-spawning) fishery, where blue grenadier is caught in mixed bags with other fish stocks by small boats, and the major winter (spawning) fishery that is focused off western Tasmania, where most of the catch is taken by a factory trawler.

This fishery is rather unique in Australia as a small number of large operators take the vast majority of the TAC. The fishery is highly recruitment driven, i.e. dependent upon years where there are large numbers of juveniles surviving, interspersed with extended periods of poor levels of reproduction. Current estimates of the strongest year-classes over the last 30 years are 1979, 1987, 1994, 2003 and 2009.

About the case study

The Blue grenadier fishery depends on infrequent large recruitment pulses that produce strong year-classes that support fishery production for many years. These recruitment pulses are driven by inter-annual variation in spawning success that is thought to be related to variation in the survival rates of the early life stages (i.e. larvae or small juveniles, in their first few weeks to months of life).

Little is known about the processes influencing variable survival of larvae and small juveniles in Australian blue grenadier stocks, but earlier studies suggest that climatic factors are likely important. Changes to either the average magnitude and/or frequency of these strong year classes would have a major impact on the fishery and is seen as a key vulnerability of this fishery to climate change.

This case study explored the relationship between blue grenadier year–class strength (YCS) and climatic variables that could be influenced by climate change. It also conducted a preliminary analysis of how variation in larval dispersal trajectories may influence year-class strength.

Finally, given that any potential climate change impacts on recruitment are likely to be difficult to forecast with high confidence, it is important that the harvest strategy for this fishery can deal with a variety of possible recruitment scenarios and continue to recommend appropriate catch levels. This case study therefore also looked at the performance of the current harvest strategy framework in protecting the stock from collapse under various recruitment regimes.

Key effects of climate change

We found that blue grenadier YCS was related to winds and sea surface temperatures. Wind strength during the autumn period just prior to the blue grenadier spawning season and mean annual sea surface temperature together explained 59% of the variation in the YCS estimates for the 36 years from 1973-2008, and 74% for the 26 years from 1983-2008. Strong autumn winds may be more conducive to retention of larval stages in the spawning region, as preliminary analysis of larval dispersal modelling indicated that years with greater retention of larval stages along the west Tasmanian shelf region had higher YCS.

Together with analysis of a range of other climatic variables, our results suggest that windy autumns, where there is greater vertical mixing of the water column and more nutrient supply to surface waters just prior to spawning, and colder winter to spring periods, are conducive to higher YCS of blue grenadier off western Tasmania.

Projections of future wind conditions for western Tasmania under climate change scenarios suggest that changes to winds will have only a minor effect on average YCS. However, sea surface temperatures are predicted to increase by 2-3 °C by 2050. The predicted increase in temperature may have a major negative impact on blue grenadier spawning and recruitment success off western Tasmania if the water temperatures experienced by the egg and larval stages are beyond their tolerance levels.

Key unknowns in regard to climate change

A key unknown is the upper temperature tolerances of the eggs and larvae. There also remains high uncertainty around how climate change will influence changes in sea temperatures at depths below 400 m where blue grenadier spend a large portion of their lives. This hinders our ability to predict if there will be changes in migratory patterns or distribution.

Poor understanding of the juvenile (first year of life) ecology and distribution is a key knowledge gap limiting understanding of how climate change may influence blue grenadier fishery production.

Improving the capabilities of our models to conduct modelling of larval dispersal under future climate scenarios will be important for assessing implications of climate change.

While it is clearly difficult to predict changes to the dynamics of YCS due to climate change, simulation testing of the current assessment framework indicated that the harvest strategy is capable of protecting the stock from long-term decline under a range of potential recruitment dynamics. However, the exercise clearly demonstrated that changes to recruitment dynamics could have a major impact on how the fishery operates under the harvest current control rule, due in large to part to a greater uncertainty in the catch dynamics.

Responding to change

Existing capacity for the fishery to adapt

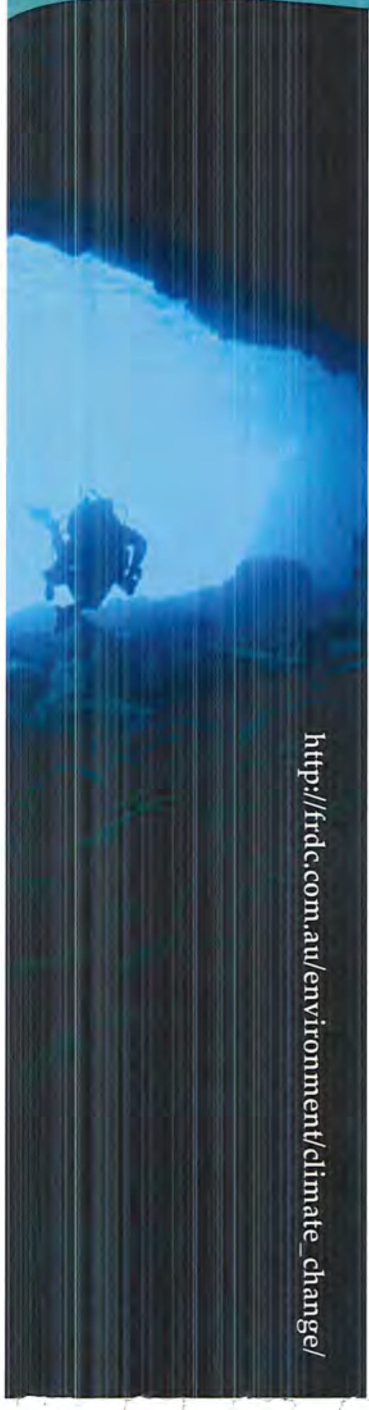
The most likely effects of climate change on the blue grenadier fishery are changes in frequency and or magnitude of the strong year classes that drive fishery production. This may mean that the dynamics of fishery production (catches) may change from the industries contemporary experiences. Distribution and seasonal migratory patterns, such as for spawning, may also be influenced by climate change. The tractable adaptations to such changes are limited but include changes in areas, times or depths fished, and changes to fleet size or gear used.

Options for improving assessment frameworks

It is possible that blue grenadier growth, mortality or other parameters might be affected by changes in surrounding environmental conditions (e.g. water temperature, prey availability). While this was not considered specifically in this work, the key assumptions used in the stock assessment model are reviewed and agreed upon by fishery and biology experts prior to their implementation. This allows frequent opportunity for observed or inferred changes to a parameter to be incorporated within the stock assessment model. In addition, more episodic recruitment could lead to major cycles in fishery production with intermittent periods of low or even zero TAC (catches). Under such scenarios, a review of control rules and fishery management plans/objectives may be required to ensure the economic performance of the fishery is maximised.

Possible planned adaptations to consider in the future

Possible adaptation actions were elicited from stakeholders in response to the potential climate change impacts. The main impacts were listed as: changes in location, timing and intensity of the spawning aggregation; lower productivity through changes in recruitment dynamics; increased interactions with protected species, and reduced availability of the stock. Potential adaptations included reducing catch quotas and/or effort, moving fishing season dates, removal of restrictions on fishing depths, changing target species and shifting areas fished.



Barriers to change

We found very few potential barriers to adaptation for the blue grenadier fishery. The fishery covers a single jurisdiction, and the goals and objectives of fishery management are clearly defined. The fishery is also confined to a small number of large operators so the demographics of the fishery are not as diverse as some larger fisheries and therefore it appears the opinions regarding management change are quite similar. The main barriers highlighted included: costs associated with altering fishing practices, timing or quota, limited options for diversification, impacts on other stocks if changes in target species.

Knowledge/data requirements into the future

The key knowledge/data requirements identified were:

- Increased collection of water temperature depth profiles to help improve forecasting models.
- Improved monitoring of reproductive aggregation behaviour by collecting time series of reproductive condition of fish in trawl shots, with associated data on depth of capture, water temperature at depth of capture and at the surface, sex ratio etc.
- Improved modelling of larval dispersal, particularly the spatial resolution and ability to investigate realistic future climate change scenarios of larval dispersal.
- Use of otoliths to study how climate regime changes might relate to/influence growth rate variation and implications for assessment modelling.
- Data on juvenile abundance and distribution to validate model YCS estimates and improve understanding of juvenile ecology.
- Controlled studies of egg and larval temperature tolerances.

Ensuring that the fisheries of south-east Australia adapt effectively to climate change will require robust scientific understanding and the development of management systems that will allow negative impacts to be mitigated and opportunities that arise to be seized.

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Photo credits: Bruce Barker, Elsa Gärtner, Rick Stuart-Smith, Geoff Tuck, CSIRO and Fisheries Victoria

South East Australian Program

Preparing fisheries for climate change

ROCK LOBSTER fact sheet

Temperatures recorded off the east coast of Tasmania over the last 70 years have shown that this region is warming at 3.8 times the global average.

Over the next century, the marine systems of south-east Australia are expected to continue exhibiting some of the largest climate-driven changes in the Southern Hemisphere, with substantial changes to ecosystems. The subsequent flow-on effects to communities and businesses will depend, in part, on how well fishing industries and resource managers can adapt to these challenges.

Southern rock lobster was one of four case-study fisheries selected to identify likely effects of climate change and highlight how fishery assessment and management frameworks could be adjusted to better consider climate change.

The fishery

The Southern Rock Lobster (*Jasus edwardsii*) resource supports important commercial and recreational fisheries across Western Australia, South Australia, Victoria and Tasmania. The total annual catch is approximately 3000 tonnes with an estimated gross commercial value of AUS$200 million. Fishing has involved the use of baited pots since the late 1800's in most jurisdictions.

All fisheries are managed under management plans that have been separately developed within each jurisdiction. Management tools include limited entry to the fishery, gear limitations and spatial or temporal closures, as well as minimum legal sizes and total allowable commercial catches (TACCs). Collectively these approaches have been successful and harvests are assessed as being sustainably managed.

About the case study

Patterns in production of other rock lobster fisheries, and Southern Rock Lobster in particular, show that the fishery is primarily vulnerable to two factors; (i) changes in the numbers of the inshore young lobsters settling of the inshore reefs each year (ie levels of recruitment to the fishery); and (ii) management decisions on allowable catches each year, and how responsive this is to changes in recruitment.

For this reason, analyses of the relationship between environmental process and the rock lobster fishery focused on the potential for climate change to alter fishery recruitment and the ability of management systems to respond.

Links between environmental processes and settlement was examined using data on the numbers of the first bottom-dwelling or benthic stage (called puerulus) from monitoring programs across all jurisdictions. This project was the first attempt to examine environmental drivers of Southern Rock Lobster recruitment across the range of the Australian fishery and across all available environmental data including wind, current and wave strength in addition to oceanic indices such as the Eastern Australian Current index (EACI) and the Southern Oscillation Index (SOI).

How changes in the physical environment may affect lobster production

Southern rock lobster eggs are carried by female lobsters living on reef on the continental shelf. After hatching, the larvae swim up into the water and are pushed by currents from the continental shelf into oceanic waters. It is thought that environmental factors such as wind strength and directions affects their ability to make this journey. Once in oceanic waters beyond the continental shelf they drift for 12 to 24 months feeding and slowly growing larger. Changes in oceanic current strength and direction are thought to affect the dispersal of this larval stage.

After the planktonic larval stage they reach a short lived stage known as puerulus which again involves a journey across the continental shelf from oceanic waters back to reef, which can be affected by environmental conditions. If they successfully find coastal reef they settle and begin life as a benthic or bottom-dwelling rock lobster. The number of these puerulus settling inshore was below average for many parts of coast from roughly 2000 to 2010, depending on location. As a consequence, the total allowable catch of all Southern Rock Lobster fisheries was reduced.

The decline in puerulus between 2000 and 2010 followed a period of increase in stock abundance and egg production so this raised the question of whether the decline in recruitment was caused by some environmental or climate change related process.

This project identified that puerulus settlement followed broadscale patterns across large areas of the fishery and in some areas these trends correlated with wind strength and current strength. However, these trends were not consistent from region to region and where they were observed, the scale of effect was only weak. There is clearly much more to learn about the processes driving recruitment of lobsters and it may be that biological factors such as algal blooms or abundance of predators of larvae in the open ocean are critical.

While specific environmental factors that caused this pattern of declines in recruitment were not clear, it does illustrate the type of event that could occur with climate change through changes in patterns of larval dispersal and survival. If climate change has an effect on future recruitment we need to have management that is effective when there is uncertainty

Vulnerability of assessment and management systems to climate change

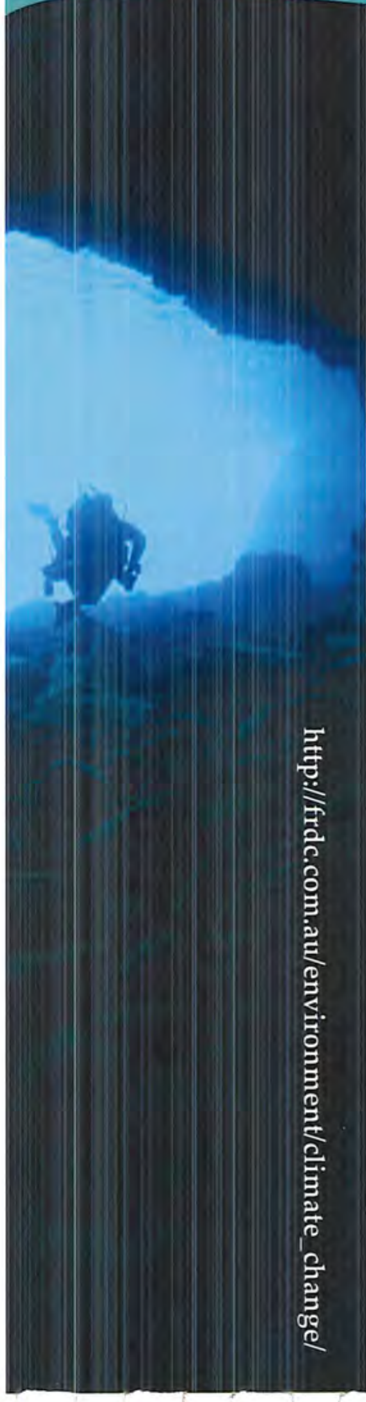
The greatest concern from climate change for lobster fisheries is that settlement and future recruitment of lobsters to the fishery will reduce faster than management can respond. All Australian rock lobster fisheries have some autonomous capacity to respond to lower recruitment by reducing the total allowable catch. This process has protected stocks by lowering catches in response to lower settlement between 2000 and 2010.

However that experience of low settlement also highlighted some areas of management that required improvement, which were the speed of response and also the need to revise expectations of the "normal" or "typical" situation in the fishery. Management decisions made in these fisheries from 2000 to 2010 assumed that settlement of lobster larvae was variable from year to year but within ranges that were considered plausible from past experience. This meant that management systems used for the fishery were not well prepared for declines in recruitment that remained low for a longer period than had occurred at any time over the previous 30 years.

Assessment and management suited to change

The project examined the process of quota setting in the presence of uncertainty about future recruitment that could possibly occur with climate change, concluding:

- Biomass targets for the fishery should be set conservatively and that the probability of reaching these targets should be higher than 50%.
- Using economic targets for the fishery should be encouraged and provides good protection against climate change. This was because high economic yield occurred when lobsters were abundant so that cost of fishing was low.



- Much higher levels of biomass than occur in the fishery at present would create much greater resilience to any future periods of low recruitment.
- Rebuilding stocks to high levels of biomass would require setting low catch limits although the economic impact of this was minor because cost of fishing would also be reduced.

Knowledge requirements into the future

The ability of fishery management to respond to periods of low recruitment is improved by having access to good data on recruitment to the fishery.

There are many ways to collect this information but one of the most effect and lowest cost options are programs where commercial fishers measure some of the undersize lobsters in their catch. These monitoring programs are now underway across most of the fishery and will be increasing in value for responding to changes in the fishery as the time series become longer.

Ensuring that the fisheries of south-east Australia adapt effectively to climate change will require robust scientific understanding and the development of management systems that will allow negative impacts to be mitigated and opportunities that arise to be seized.

FRDC · University of Tasmania IMAS · CSIRO · SARDI · Victoria Department of Environment and Primary Industries · NSW Industry & Investment

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Photo credits: Elsa Gärtner, Adrian Linnane, Rick Stuart-Smith, IMAS and SARDI

South East Australian Program

Preparing fisheries for climate change

SNAPPER | fact sheet

Temperatures recorded off the east coast of Tasmania over the last 70 years have shown that this region is warming at 3.8 times the global average.

Over the next century, the marine systems of south-east Australia are expected to continue exhibiting some of the largest climate-driven changes in the Southern Hemisphere, with substantial changes to ecosystems. The subsequent flow-on effects to communities and businesses will depend, in part, on how well fishing industries and resource managers can adapt to these challenges.

Snapper was one of four case study fisheries selected to identify the likely effects of climate change on fisheries in south-east Australia, and to evaluate how well fishery assessment and management frameworks may perform given expected future environmental change.

The fishery

Snapper (*Chrysophrys auratus*) is a large, long-lived, demersal finfish species that is distributed throughout coastal waters around the southern two thirds of the Australian mainland. The species supports significant commercial and recreational fisheries in each of the mainland states of Qld, NSW, Vic, SA and WA.

In the different commercial fisheries and jurisdictions, snapper are targeted with a number of different gear types that include handlines, longlines, haul seines, fish traps and demersal trawls. In recent years, the national annual commercial catch has varied from 1,600 to 2,000 t. The commercial sector dominates catches in SA and NSW, and the recreational sector dominates catches in Queensland and Victoria.

The various State-based fisheries are managed independently of each other through different regulations.

About the case study

Snapper was selected as a case study species to examine the likely effects of climate change because of its high commercial value and recreational significance, and because it is distributed over a broad latitudinal range. Furthermore, it was considered that this case study would provide useful insight into how fisheries can adapt to change when there are changes in the distribution of species.

Two significant vulnerabilities of snapper to climate change were identified. First, the number of new individuals surviving and entering the fishery each year (new recruits) in SA and Vic is highly variable and ultimately drives population biomass and fishery productivity. Consequently, the relationships between environmental variables that might be influenced by climate change and recruitment were considered, in order to project the likely effects of climate change on recruitment dynamics.

The second potential vulnerability to climate change relates to the considerable latitudinal variation in the timing of the reproductive season of snapper for which the environmental cues remain poorly understood.

Key effects of climate change

Recruitment variability of snapper is now thought to be driven by variable survivorship of the early stage larvae. Inter-annual variability of such survivorship is however not a simple relationship with physical factors. Various environmental factors including water temperature, river flow, associated nutrient input regimes and plankton food chain dynamics interact to determine the optimal time periods for larval survival and survival rates. The complexity of this system complicates the possibility of developing sufficient understanding to predict the consequences of climate change on recruitment dynamics.

Snapper populations around the Australian continental shelf generally spawn when SST (sea surface temperature) is between 18 to 22°C. This temperature range largely corresponds to the experimentally determined range of physiological tolerances for survival of snapper eggs and larvae.

We used forecast modeling was to assess how the temporal window for this optimal temperature regime may change at different places over the next 50 years. The results indicated that in the future for such regions as Qld, northern NSW, and the northern gulfs of SA, there may be no period during the year when the SST falls within the tolerated temperature range. This may mean that snapper cannot maintain viable, self-recruiting populations in these regions.

In contrast, SST regimes in northern and eastern Tasmania are predicted to become more suitable for snapper spawning as these regions continue to warm. Consequently, in the future the broad-scale patterns of distribution and abundance of snapper down the east coast of Australia may well change due to the changes in SST regimes, as a direct consequence of the physiological tolerance ranges of the eggs and larvae.

Key unknowns in regard to climate change

Commercial fishery monitoring programs are established in each of the mainland states, collecting commercial catch and effort data. If maintained, these should be sufficient to detect significant changes in the distribution and abundance of snapper that may result from temporal or spatial changes in spawning success.

However, monitoring would need to be introduced to detect predicted increases in abundance in Tasmanian waters. Furthermore, there is limited data on reproduction of snapper along the central and southern NSW coast, an area where snapper reproduction, biomass and fishing opportunities could potentially increase in the future due to changes in SST regimes.

In the bay and gulf spawning stocks (i.e. SA and western Victoria-Port Phillip) enhanced collection of data relating to the dynamics in nutrient supply, plankton assemblages and snapper recruitment are necessary for the monitoring of the effects of climate change on recruitment variability and ultimately stock productivity. It is likely

that more advanced approaches including ecosystem or biophysical models will be required to make predictions on climate effects on snapper recruitment regimes in these sheltered water spawning and nursery areas.

Responding to change

Existing capacity for the fishery to adapt

The most likely effects of climate change are changes in distribution and abundance of adult snapper that will affect fishery productivity at local as well as larger spatial scales. The tractable adaptations to such changes are limited but include: shifting fishing operations to new times or places; increase or decrease target effort appropriately; or if operating in a multi-species fishery, shift effort onto other species. A barrier to adaption may include multi-jurisdictional management, for example if fishers cannot follow shifts in snapper distribution across State borders.

Options for improving fishery assessment frameworks

There are a number of options for improving assessment frameworks for snapper. These include:

- establishing a means by which monitoring, assessment and management of cross-jurisdictional snapper stocks can be achieved
- establishing fishery independent measures of fishable biomass, and therefore moving away from indicators that are subject to the influence of fisher behavior, and changes in fish behavior and distribution
- better monitoring of the catch and effort by the recreational sector
- developing harvest strategies that involve both the recreational and commercial sectors and take into account socio-economic objectives as well as biological sustainability and environmental effects on productivity.

Possible planned adaptations to consider in the future

To better prepare for future changes, it may be beneficial to:

- implement single-stock, cross-jurisdictional assessments for the appropriate stocks
- increase monitoring to allow detection of changes in patterns of distribution and abundance, such as in Tasmanian waters and to manage such stocks appropriately to allow establishment of breeding populations
- undertake re-stocking of areas that have been negatively impacted (i.e. prolonged periods of recruitment failure)
- implement measures to protect or enhance particularly significant areas of habitat or enhance habitats with artificial reefs in other areas where appropriate.

Barriers to change

Establishing cross-jurisdictional regulations will be difficult, stocking or re-stocking is expensive and may also create issues with genetics and possible disease. Additional monitoring or introducing fishery independent monitoring is also expensive and so any planned changes to assessment or monitoring frameworks will need to be carefully considered by all stakeholders involved.

Knowledge/data requirements into the future

Further investigations of recruitment variability are required to enhance our understanding of the complex interactions between biological processes and the biological and physical environment. Then, in order to better understand the effects of climate change, we will need better predictions of rainfall, and river flow regimes for places like Port Phillip Bay. Such predictions would then be used as input to biophysical models that are currently under development to provide better quantitative measures of the effects of variable recruitment on fishery productivity. For the east coast stock (with oceanic spawning), improved oceanographic forecast modelling is important for understanding the implications of changes in the East Australian Current to larval dispersal, survival and regional recruitment patterns.

Ensuring that the fisheries of south-east Australia adapt effectively to climate change will require robust scientific understanding and the development of management systems that will allow negative impacts to be mitigated and opportunities that arise to be seized.

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Photo credits: Anthony Fowler, Elsa Gärtner, Paul Hamer, Andrew Pender, Rick Stuart-Smith and SARDI

Policy musings -

Governments will always play a huge part in solving big problems. They set public policy and are uniquely able to provide the resources to make sure solutions reach everyone who needs them...

Bill Gates

Energy and environmental regulation, transportation, and broadband policy all benefit when legislators have a basic grounding in the technical concepts behind business models, products, and innovation..

John Sununu

The markets want to force us to do certain things. That we won't do. Politicians have to make sure that we're unassailable, that we can make policy for the people.

Angela Merkel

....success is determined by an intersection in policy and politics and that you can't be neglecting of marketing and P.R. and public opinion.

Barack Obama

A policy is a temporary creed liable to be changed, but while it holds good it has got to be pursued with apostolic zeal.

Mahatma Gandhi

The one who adapts his policy to the times prospers, and likewise that the one whose policy clashes with the demands of the times does not.

Niccolo Machiavelli

Repairing Australia's estuaries & wetlands – bringing back productivity

- Australian fisheries a sustainability reality check

www.frdc.com.au

Australian pet cats eat two times the entire catch of the SE Trawl fishery....all of it imported, generally from unsustainable fisheries

Australia's wild fisheries -

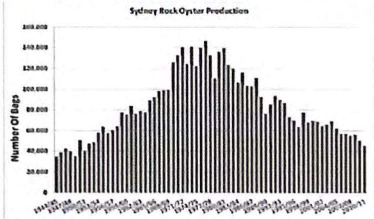
Australian fisheries catching sector predominantly sustainable....closures, limited entry, bycatch

[Some exceptions e.g. Indigenous dugong take]

NOT sustainable - our farm! Habitat is grossly impacted by other primary industries &coastal development

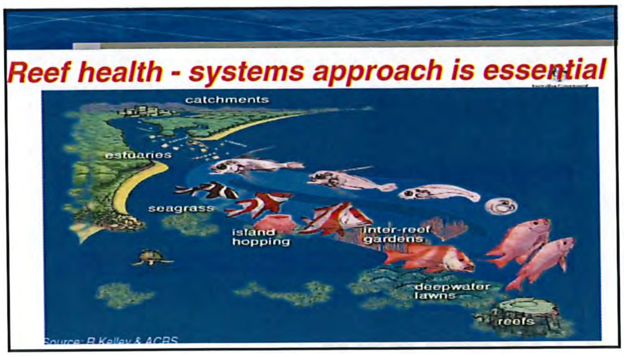
Can "blue carbon" be used to claw back and repair habitat?

Bags – Sydney Rock Oyster 1950 to 2011

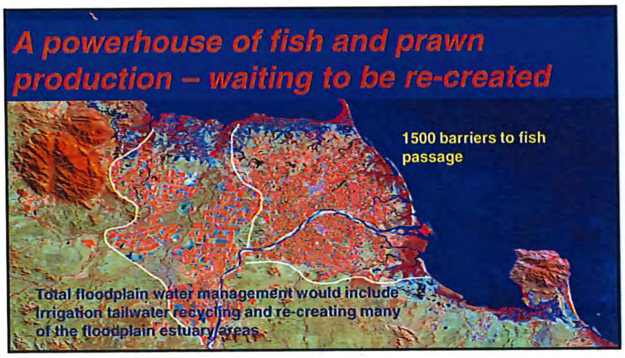


Major production losses post 1970's relate to decline in estuary health, even though production techniques have improved.

Lisa Kirkendale, Pia Winberg, Ana Rubio, Peter Middelfart (in prep). "The Australian oyster industry: Challenges and Opportunities" Reviews in Aquaculture


Reef health - systems approach is essential
catchments
estuaries
seagrass
island hopping
inter-reef gardens
deepwater lawns
reefs
Source: R Kelley & ACRS


Estuary dependence & Australian fisheries
❑Over 75% of the east coast Australian seafood catch is estuary dependent [no figures for northern Australia...but probably similar]
❑ WA and SA – nearshore and embayment driven productivity
Wetlands & tidal processes – without them fish populations for both recreational and commercial fisheries are vastly reduced


A powerhouse of fish and prawn production – waiting to be re-created
1500 barriers to fish passage
Total floodplain water management would include Irrigation tailwater recycling and re-creating many of the floodplain estuary areas


Creek Blockage
Floodgating & drainage
Training walls
Tidal Constriction
Drainage & Levees
Clarence estuary....some repair opportunities


Levees, drains, algae & de-oxygenation – how to start a "black water event"......a fish and prawn kill.


Relocate levee
Re-think drainage to restore wetland function
Lake Wooloweyah, bring back the key drivers of productivity - tidal flow and wetland function


Business as usual is drained poorly productive wetlands.....

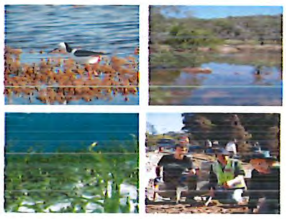
Floodgate and drain removal Clarence floodplain **– soil carbon + biodiversity + productivity + fishery + water quality**

Repairing Australia's estuaries & wetlands – bringing back productivity

- coastal ecosystems and carbon mitigation, can we enter the marketplace?

www.frdc.com.au

Blue Carbon and coastal ecosystem repair



Anissa Lawrence & Catherine Lovelock

Quantifying Benefits to Drive National Investment in Coastal Wetland Repair

TierraMar CONSULTING

Blue Carbon - 3 key ecosystems

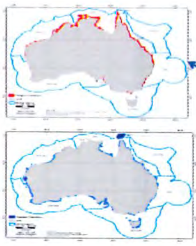
All Photos Anissa Lawrence

"that carbon stored and cycled by the biota but especially the soils of tidal marshes, mangroves and seagrass meadows"

< 0.5% of seabed - capture and store majority of all carbon in ocean sediments

TierraMar CONSULTING

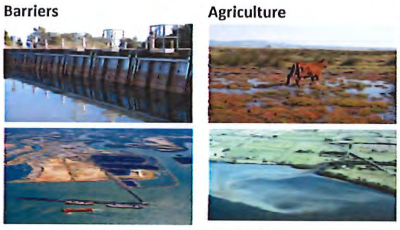
Australian distribution



991,000ha mangroves
1,376,500ha saltmarsh (including saltpans)
9,637,100ha seagrass
Rich spp diversity for all
< 1% of total land area

Estuarine ecosystems - a history of being drained, degraded and lost

Barriers | **Agriculture**



Current Australian losses
- 1-2%p.a saltmarsh
- 0.01-2%p.a mangroves
- 0.05%p.a seagrass

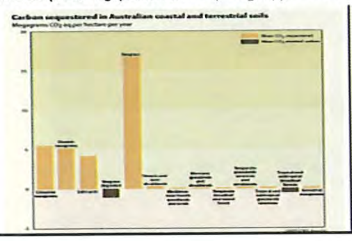
- *Disturbed wetland, drained for pasture in 1950s in Hunter River, NSW - loss of 40% of organic carbon over 50 yrs (Howe et al 2009)*

Development | **Pollution**

TierraMar CONSULTING

Australia's coastal wetland ecosystems **sequester C in their soils at rates of up to 66 times higher** than those of our terrestrial ecosystems, including forests, on a per hectare basis

<1% of landmass, but 39% of average national annual total carbon burial for all ecosystems (183.2 Tg (million tonnes) CO_2 eq yr^{-1} of a total of 466.2 Tg CO_2 eq yr^{-1})

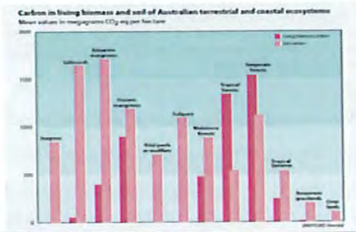


Notes
-
- Australian coastal estimates within global ranges
- sensitivity analysis required
- terrestrial comparison based on CSIRO modeling

TierraMar CONSULTING

Australia's coastal wetland ecosystems **store 5 times more carbon in their soils** than those of our terrestrial ecosystems, including forests, on a per hectare basis

Store on average at least 5% of all carbon stored in Australian ecosystems (biomass and soils) (at least 22 Pg (billion tonnes) CO_2 eq of a total of 441.2 Pg CO_2 eq)



Notes
- Australian coastal estimates within global ranges
- sensitivity analysis around uncertainty required
- terrestrial comparison based on point data

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Emissions

Source	Mt CO_2 -e	% of Australia's net emissions
Livestock[a]	58.1	9.7
Crops and Soils[b]	14.2	2.4
Burning[c]	12.5	2.1

- For degraded and lost coastal wetland ecosystems, a crude estimate - releasing between 0 - 0.2Tg CO_2 eq/yr [need to add melaleuca and sedgelands systems]

  [just mangrove and saltmarsh = extra 4,397 cars/yr or 37% Tas energy generation or "lots of cow burps"]

- Page and Dalal (2011) – 25% loss of organic carbon from the top 1m in the first 50 years following drainage
- When healthy - negligible amounts of CH_4 and N_2O and in some cases, can act as CH_4 sinks as well as C sinks

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Australian Government
Fisheries Research and Development Corporation

Repairing Australia's estuaries & wetlands – bringing back productivity

coastal ecosystems- who benefits?
why is our public policy so dysfunctional?

www.frdc.com.au

Key Benefits in Summary

1. **Community and commercial fisheries** - estuary dependence of most of our target species....and where most of us recreate
2. **Simplest food security** – no fertiliser or cultivation needed!
3. **Highest value protein source** – healthy oils, low fat and low energy footprint
4. **Biggest carbon sequestration opportunity** – climate mitigation outcomes at nil risk in our most productive ecosystems
5. **Essential Coastal buffering / flood management / water quality and quantity** – extreme events, nutrient polishing, sediment capture
6. **Greatest Landscape amenity** – where over 85% of us live

Public Policy – Changing Paradigms

1. Going beyond the "tyranny of the commons" .... to ***highly valued public and private assets***
2. Multiple community benefits require ***multi-objective policies and R&D for multiple outcomes***
3. ***Blue carbon*** – a topical place to start but.....???
4. ***Turning the Tide on Past Mistakes*** – a "no regrets" optimisation of productivity from our landscapes initiated by FRDC & Biodiversity Fund

Requires a whole of RDC and agency approach

where to for Australian primary industries?

Public Policy – Changing Paradigms

5. **Rationale for investment** – the down side of doing nothing - can we really afford to continue to loose these assets, their ecological values and catalyse conflict across primary industries?
6. **Australia-wide in coverage but focused investment in repair** – there are less than 90 severely modified estuaries....all the bigger floodplains where cropping and grazing dominates
7. **Empowering local action, primary industries and community in partnerships** – similar to UK, EU & USA models
8. **Incentivising benefits and legacy** – a multi-player and multi-benefits approach
9. **Coordinated R,D&E** – capturing repair strategies, ecological outputs and community outcomes for all primary industries

Challenging for RDCs and agencies

where to for Australian primary industries?

Repairing Australia's estuaries & wetlands – bringing back productivity

Australian Government
Fisheries Research and Development Corporation

- multiple benefits if we can meet the challenges of repairing past mistakes

www.frdc.com.au

My "fish" – but it is wind and solar powered. Fibreglass [hydrocarbons] so it has permanently sequestered a lot of carbon. When in Mackay marina the additional carbon sequestration is estimated at 1 tonne/annum of coal dust.......still awaiting my carbon credits!

My thesis

1. OK to have discussions about resource competition [commercial / recreational / conservation] **IF you have a resource to share**

2. For Australia's estuary dependent fisheries **our resource has markedly declined**

3. **Priority 1 is to repair that resource**....and after we have done that we can argue about resource sharing

4. **Many of us have already worked hard** to protect fisheries habitat and to repair our estuaries.

5. Now just might be **the right time** to gain political and community support for major investment in estuary and fisheries habitat repair........

& by the way

Super trawlers or **super estuaries?** .....

* the Murray Lower Lakes & Coorong were Australia's largest estuary.
* 100 jewfish [Mulloway] fishermen weren't wrong!
* significant role in larval / juvenile dispersal along Australia's south coast

so my manifesto

Bring back the porpoises to Wellington! .....and after that we will talk about marine parks and restrictions to fisheries

[Its as simple as a ring main irrigation water system for agriculture and a improved flow regime. The $ are already in the Govt's Murray Darling Infrastructure Initiative.....]

Estuaries & wetlands repair – key to productivity

Naturally a mosaic of tide, sand, seagrass, mangroves, salt marshes and fresh to brackish wetlands

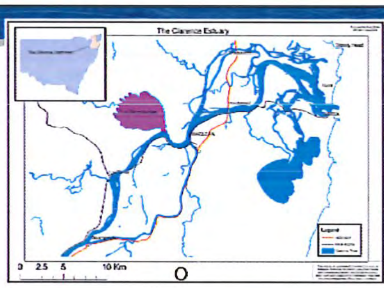
Estuaries & wetlands – biodiverse and the most productive ecosystems

Estuaries & wetlands – treasured but often grossly damaged landscapes....behind the idyllic scenes

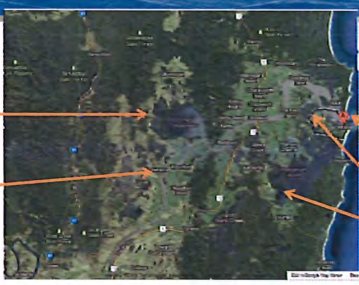
Estuary dependence & Australian fisheries

- *Over 75% of the east coast Australian seafood catch is estuary dependent [no figures for northern Australia...but probably similar]*
- *WA and SA – nearshore and embayment driven productivity*
-

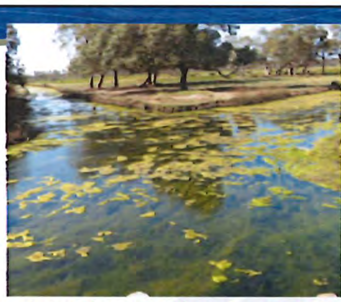
Wetlands & tidal processes – without them fish populations for both recreational and commercial fisheries are vastly reduced



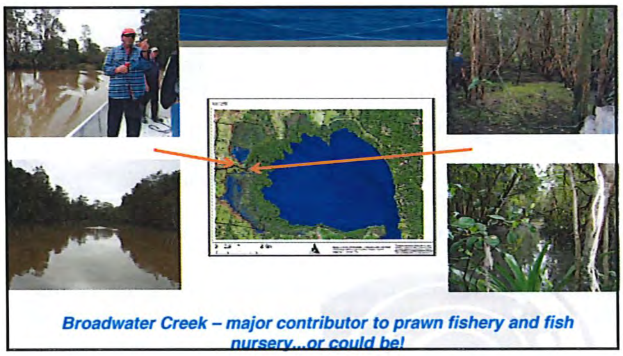
Case Study – Clarence estuary....repairing past mistakes

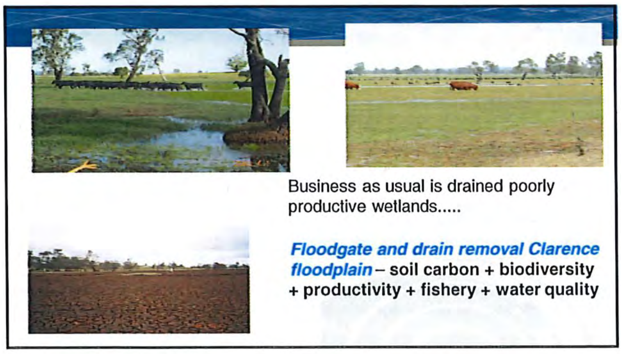


Clarence estuary....some repair opportunities



Levees, drains, algae & de-oxygenation – how to start a "black water event".......a fish and prawn kill.





Work so far

Recognition of the imperative for estuary repair, works & plans of management.

Examples include:

- Hexham Swamp, Hunter
- Floodplain Management Group in northern NSW,
- NSW State Govt grants up to $40K,
- Plans of Management for Clarence / Tweed / Richmond etc

Black water flood events have decimated both recreational and commercial effort in northern NSW

GBRMPA undertaken inventories of barrages to fish passage in GBR catchments – e.g. 1500 barriers just in Burdekin floodplain

Repair works are "change".... and change is challenging

A powerhouse of fish and prawn production – waiting to be re-created

Reef health - systems approach is essential

Why should we bother?

- Global food security
- Low energy footprint
- Carbon sequestration
- Community benefits
- Water quality and catchment buffering
- Continued declining fisheries productivity
- Well recognised "past mistakes"
- Funding opportunities – e.g. Biodiversity Fund

As a fishing community with knowledge we have an obligation to advocate landscape optimisation - for multiple community benefits

Global food security

- ***Over 3 Billion people rely on seafood for at least 15% of their protein [FAO 2007]***
- ***80% of the world's seafood production occurs in developing countries***
- ***More than $100B – value of the global seafood trade***

Wild fisheries - no fertiliser or chemical inputs, high protein, low fat – the healthiest food & in Australia predominantly sustainable economic yields

Wild seafood – a low energy footprint

Edible protein energy return on investment, various animal protein production services [Tyedmers, Watson & Pauly]

Carp (extensive pond culture)	110 – 11
Mussel (longline, Scandinavia)	10 – 5
Wild fisheries (global)	8.0
Beef (pasture based, USA)	5.0
Beef (feedlot, USA)	2.5
Atlantic salmon (cage culture, Canada)	2.5
Lamb (pasture based, USA)	1.8

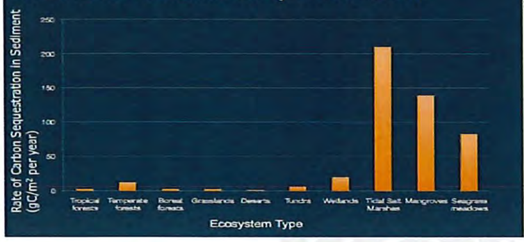
Rule of thumb for all Australian primary industries – more efficient in production rates versus input costs

Carbon sequestration

- About 55% of all biological carbon capture is "blue" carbon – ie: in the world's ocean ecosystems
- Wetlands, lakes & estuaries comprise less than 5% of the world's land based plant biomass but store equivalent carbon to the other 95% of land based biomass
- For Australia the % figures are probably even more favourable [and no bushfires]
- ....or globally, wetlands, lakes and estuaries capture and store about half the world's transport sector emissions annually

Carbon sequestration + fisheries habitat + biodiversity + productivity + shore protection + aquaculture – smart public investment

Coastal ecosystems have very high rates of carbon sequestration.



Water quality

- ❑ ***Floodplains & wetlands can assimilate most of the catchment land use impacts – if natural processes operate***
- ❑ ***Water quality AND habitat are required for a biodiverse fish assemblage***
- ❑ ***Drained wetlands through flood events create changed pH + "red spot" and sometimes "black water" massive fish kills***
- ❑

Wetlands - part of the frontline of catchment health

What is next?

FRDC needs strong support and high priority repair proposals for wetlands and estuaries so that –

- ❑ fisheries and aquaculture do not continue to be "Cinderella primary industries" and
- ❑ Australian public policy gives pre-eminence to retaining and repairing coastal habitat

We need your knowledge and nominations
frdc.programs@frdc.com.au

Estuaries & wetlands repair – key to productivity

fishing lines
The magazine of Victoria's Peak Recreational Fishing Body
WINTER 2014
UNDERSTANDING
Fish Habitat
More Habitat = More Fish
Rehabilitating rivers
Tackling climate change
April Vokey
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Published by VRFish
Victorian Recreational
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Executive Officer: Dallas D'Silva
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Welcome

Welcome to the Winter 2014 edition of VRFish's *Fishing Lines* magazine.

The theme for this issue is "Habitat". The articles presented in this edition highlight a wide range of habitat protection, habitat restoration and habitat conservation projects currently being undertaken across Victoria.

The concept of habitat enhancement has been understood and adopted by concerned recreational fishers across the world and Victorian recreational fishers are embracing the benefits of habitat revitalisation with enthusiasm.

A healthy aquatic habitat leads to healthy fish populations and health fish populations lead to healthy fisheries. However, habitat is not only for fish but also for the myriad of aquatic organisms that are part of a healthy and sustainable ecosystem.

This edition showcases some of the innovative protection and restoration initiatives supported by the Victorian "Recreational Fishing Licence Trust Fund" and the Victorian government's $16 million "Recreational Fishing Initiative Fund" to preserve and protect vital freshwater and saltwater habitat in Victoria.

This investment by recreational fishers and the Victorian government demonstrates a vision for Victoria that will provide a strong basis for exciting recreational fishing opportunities for future generations.

> This edition showcases some of the innovative protection and restoration initiatives supported by the Victorian "Recreational Fishing Licence Trust Fund" and the Victorian government's $16 million "Recreational Fishing Initiative Fund" to preserve and protect vital freshwater and saltwater habitat in Victoria.

VRFish has been at the forefront of habitat remediation efforts for many years and we have partnered with local Councils, community groups and government departments to identify high priority areas for conservation, management, or research because they are rare, sensitive, stressed by development or important to ecosystem function. Fish need healthy surroundings to survive and reproduce and habitat is the vital ingredient needed to ensure that fish can successfully live, feed, reproduce and grow to maturity.

VRFish's key long-term strategy for delivering community-wide benefits to Victorian recreational fishers includes the development of habitat remediation policies and practical involvement in developing innovative solutions to habitat degradation.

Many millions of recreational fisher licence funds have been invested across Victoria to construct fish-ways and fish ladders to allow fish to move past man-made barriers in order to spawn. Also, the installation of in-stream habitat structure, re-snagging of rivers and the construction of new artificial reefs at Frankston, Altona and Port Arlington (funded by the government's Recreational Fishing Initiative Fund) will have tremendous long term benefits for both recreational fishers and the greater Victorian community.

The majority of recreational fishers understands the long term benefits of healthy habitat and make exceptional environmental stewards. Productive recreational fisheries are inextricably linked to healthy marine habitats; protecting and restoring them will help support fishing communities now and for generations to come.

The VRFish mission is to increase participation in recreational fishing across Victoria and we are delivering on this outcome by ensuring that investment is targeted towards improving fish habitat, increasing the efficiency and effectiveness of fish stockings and ensuring appropriate access to fishing locations.

VRFish will continue to work to ensure habitat remediation and habitat enhancement is a high priority for Victoria.

Tight Lines

Russell Conway
Chair

Welcome to the 1st edition of *Fishing Lines* for 2014. I have now been in the job for 7 months and it has been a challenging and rewarding period.

In the last 9 months I have put together a plan to restructure our team at VRFish and this has been approved by the Board. The new structure revised my role from Executive Officer to General Manager and broadens the Finance Officer position to also include administration and business support. The biggest change involves creating a new Senior Program and Partnerships Manager (SPPM) position that replaces the Operations Manager role and creation of a Recreational Fisheries Liaison Officer role to increase engagement with grass roots fishers, angling clubs and our culturally diverse community. The structure will be progressively implemented subject to available funds.

We are currently in the process of recruiting for the SPPM role. Simon Kinniburgh has decided to leave VRFish after more than 2 years with us. Simon will be pursuing other interests aligned with his sports and recreational background. I would like to take this opportunity to thank Simon for his contribution to the organisation and wish him well for the future.

I would like to take this chance to remind our readers about 'what makes VRFish tick' and the democratic and transparent process used by VRFish in developing policy on complex fisheries issues, whether it be trout stocking in our rivers or commercial netting in Victorian bays and inlets.

We are accountable to our members through the State Council, which meets 4 times per year and is comprised of more than 50 delegates from angling and diving clubs across Victoria. The fishing clubs and associations comprise more than 40,000 recreational fishers. VRFish has members from outside the well established clubs and associations and we include grass roots fishers that are not members of clubs. Our members also have experience in the tackle and retail industries.

Our membership base is ever evolving and includes fishers from diverse cultural backgrounds. On this note, we are thrilled to have a new unaffiliated member in Quy Van. Quy is a Deakin University fisheries science graduate and Fishcare volunteer. Check out the member profile of Quy in this edition. VRFish is made up of fishers from Victorian offshore, coastal, inshore, estuarine, inland and highland fisheries. We have more than 1000 years of fishing knowledge at our finger tips and this intellectual property is invaluable. Our members are both metropolitan and regional based, while our Board is determined annually by an election process and meets 6 times per year.

We are committed to an equitable system where our limited resources are spent on important programs across the above fisheries. We endorse concerns that commercial netting in popular recreational areas can adversely impact the quality of recreational fishing experiences. Our current policy on commercial netting is that we do not support it, unless it is sustainable and responsible. This was developed through an inclusive process at a Regional State Council meeting at Torquay in March 2013. VRFish is mindful of maintaining our fish stocking, habitat improvement, enforcement/ education, infrastructure and access programs now and into the future. These are well established priorities identified by recreational fishers.

How we share our fisheries resources with other users is a sensitive and challenging issue. We agree with the concerns from recreational fishers that the balance is not right (eg - abalone regulations that unfairly restrict legitimate access). This needs constant attention by VRFish to ensure Victoria is recognised as a premier fishing destination. We have been instrumental in securing an agreement in East Gippsland that will help minimise the impact of commercial fishing on recreational beach fishers. The licence holder who operates the F.V.Maasbanker acknowledges that transiting close to shore can 'spook' schools of salmon and has agreed to transit at least one mile from the shore to minimise this risk. We have also achieved some success by working with commercial fishers in Port Phillip Bay to voluntarily restrict seine netting in the inner harbor over Easter. These are all positive outcomes that are the result of hard work and at times difficult negotiations with other user groups.

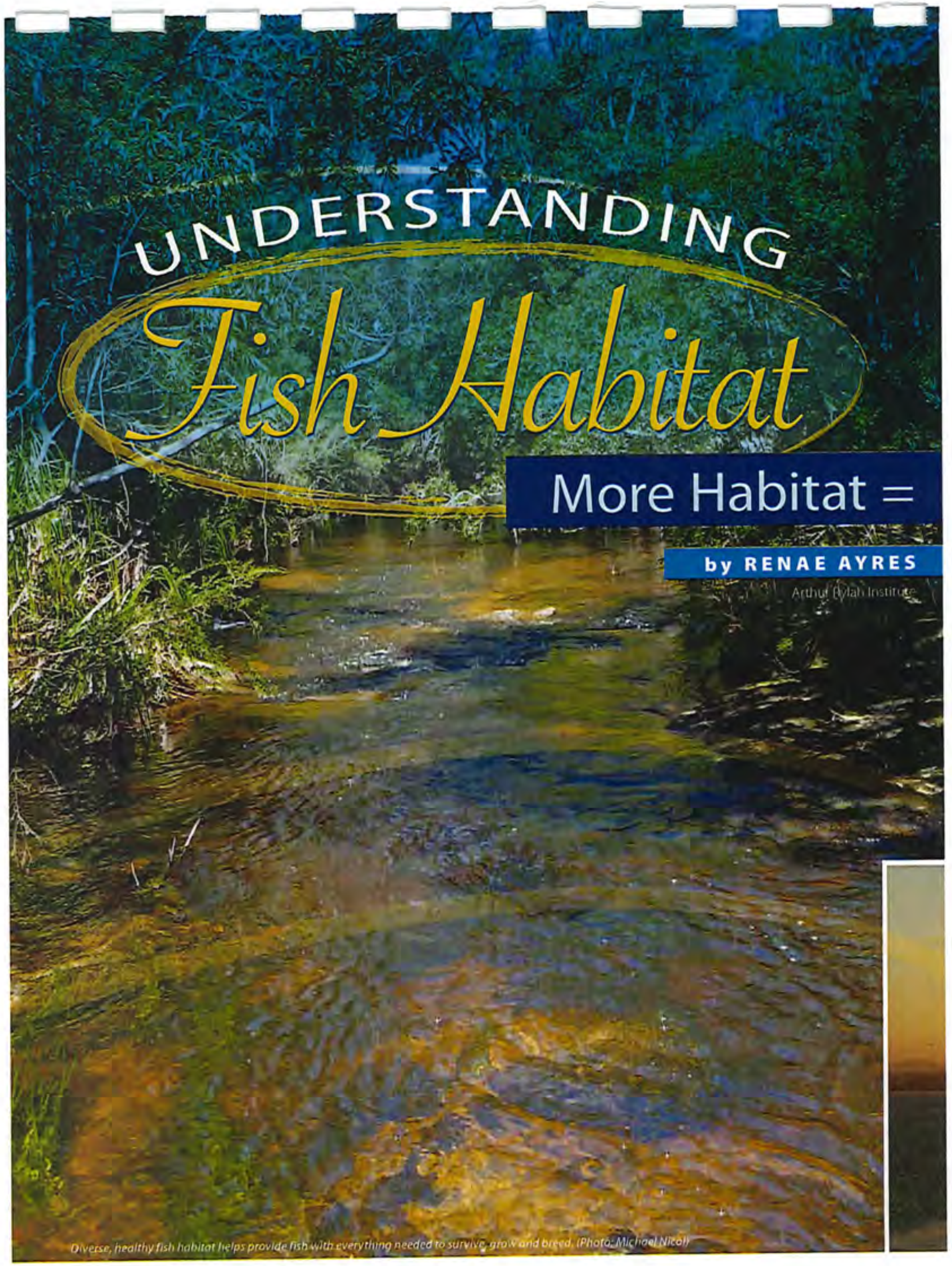
> The major theme of this edition is fish habitat. This issue ... always rates highly in any survey of where recreational fishers would like to see their licence money invested.

The major theme of this edition is fish habitat. This issue is of utmost importance to recreational fishers and always rates highly in any survey of where recreational fishers would like to see their licence money invested. After all, healthy habitat = healthy fisheries. There is now greater recognition of the importance of fish habitat at a national level thanks to agencies such as the Fisheries Research Development Corporation and the Department at a State level. It is particularly pleasing to see new partnerships being forged between recreational fishers and catchment management authorities.

Finally, we encourage constructive debate and discussion by our members and all recreational fishers on issues in accordance with our code of conduct.

Until our next edition - good fishing....stay safe on or near the water.

Dallas D'Silva
General Manager



UNDERSTANDING Fish Habitat

More Habitat =

by RENAE AYRES
Arthur Rylah Institute

Diverse, healthy fish habitat helps provide fish with everything needed to survive, grow and breed. (Photo: Michael Nicol)

Fish need healthy habitat to survive and thrive. Improving fish habitat helps make more fish and that means better fishing.

What is 'fish habitat'?

Fish habitat is where fish live. It is their home or surrounding environment.

Fish habitat includes water: freshwater, estuarine or saltwater. Water quality, as well as its depth, flow and temperature are all important. Fish habitat encompasses all aquatic environments, such as wetlands, creeks, rivers, estuaries, bays and oceans. Connections between these aquatic environments are essential for healthy fish habitat.

Physical features in the water, such as pools, riffles and reefs, as well as living and non-living structures including fallen trees ('snags'), rocks, mud, sand, coral, reeds, mangroves and seagrass, are all fish habitat. Even plants along the bank and overhanging the water contribute to fish habitat!

More Fish

Why do fish need habitat?

Fish need habitat to survive, grow and breed. Healthy habitat provides fish with everything they need to complete their lifecycle: shelter, food and areas to spawn.

Habitats need to be connected so fish can move freely to access spawning grounds, seasonal feeding areas or escape poor conditions. This is particularly important for fish species that migrate large distances, such as Murray Cod, Mulloway and Australian Grayling.

A variety of habitat is needed as different fish species prefer different habitats. In addition, the habitat required for fish eggs and larvae is usually much different to the habitat needed for adults!

The number and diversity of fish that an area can support is limited by the type and quality of habitat available. By maintaining healthy fish habitats, we can ensure healthy and sustainable fish populations into the future.

Healthy fish habitat supports healthy fisheries and recreational fishing! (Photo: Arthur Rylah Institute)

Threats to fish habitat

Processes and activities that degrade the health of fish habitat threaten our fish populations and our fishing success. Threats to habitat include:

- Damage to instream habitat, e.g. removal of logs, channelisation
- Clearing of native vegetation
- Invasion by weeds and pests
- Erosion and sedimentation
- Altered water flows and temperatures
- Degraded water quality
- Pollution and rubbish
- Loss of connection between habitats
- Constructed barriers that prevent fish passage, e.g. weirs, dams
- Unpermitted estuary entrance openings

How can we improve fish habitat?

- Rehabilitate river banks, manage weeds, replant native vegetation, control erosion
- Restore instream habitats, introduce logs, reinstate pools and riffles, revegetate native aquatic plants
- Maintain or reinstate natural flow regimes,mimic natural flows, introduce tidal flushing
- Manage livestock access,fence waterways, provide off-stream water supplies
- Improve fish passage, construct fishways, remove redundant barriers
- Enhance water quality,manage storm water, clean up litter

Get involved!

- Stay informed: link with the Fish Habitat Network, local angling clubs, VRFish, Fisheries Victoria, the Arthur Rylah Institute or Catchment Management Authorities.
- Support improving habitat: be a voice for fish! Talk to your family, friends, neighbours and even your local member of parliament about how important healthy fish habitat is for fish and fishing.
- Be a Habitat Hero: get your hands dirty for fish! Work alone, with your mates or link with a local club. Let people know what you're doing and why it's important for fish.
- Apply for grants to improve fish habitat e.g. through the Commonwealth and State governments, Catchment Management Authorities or local councils and shires.
- Fish responsibly: adhere to fishing regulations, e.g. closed seasons, bag, gear and size limits, and carefully release all unwanted catches back to the water. Refer to the Victorian Recreational Fishing Guide and VRFish Recreational Fishing Code of Conduct.

For further information please visit the Fish Habitat Network at www.fishhabitatnetwork.com.au or contact Victorian representatives:

- **Arthur Rylah Institute (Renae Ayres, 03 9450 8600, renae.ayres@depi.vic.gov.au),**
- **VRFish (Dallas D'Silva, 03 9686 7077) or**
- **Fisheries Victoria (Anthony Forster, 03 9658 4375)**

Helping make more fish... Naturally

80% of adult Murray cod live within 1 metre of a snag. (Photo: Craig Copeland)

by RENAE AYRES
Arthur Rylah Institute

What is the Fish Habitat Network?

The Fish Habitat Network is a network of people and organisations from around Australia who are dedicated to making more fish naturally by improving fish habitat. The Fish Habitat Network began in 2009 as an informal partnership between New South Wales State government and local fishers.

Since then, the Fish Habitat Network has expanded to other Australian States and Territories and now operates nationally. Recreational fishers, peak bodies, trade, government and research institutions are all working together to bring the fish back and ensure that our aquatic environments and fish communities are healthy, diverse and sustainable for future generations.

Why we exist

Recreational fishing is a popular activity in Australia. It provides social, health and well-being benefits and contributes significantly to the Australian economy. Healthy waterways with diverse and abundant habitats are fundamental for productive and sustainable fisheries - and good news for recreational fishing!

The reality, however, is that the condition of Australian catchments and waterways is degraded. This is reflected in the abundance of fish and how well fish populations can cope with droughts and floods. There are nowhere near the numbers of fish around that there once were.

Habitat rehabilitation can realistically increase the abundance and resilience of key target fish species. It has the added benefit of improving the overall health of our waterways and estuaries.

Habitat rehabilitation can realistically increase the abundance and resilience of key target fish species. It has the added benefit of improving the overall health of our waterways and estuaries. By ensuring fundamental habitats are healthy and available for fish, we are providing the basics that enable fish to survive and thrive.

Recreational fishers have an important role to play in ensuring the long-term sustainability of the fisheries upon which our sport depends. The Fish Habitat Network encourages and supports recreational fishers who are putting something back into their sport and making more fish, naturally.

What we are aiming for

Our vision

A recreational fishing community that is actively involved in managing fish habitat across Australia

Mission

To harness the skills, experience and projects within each of our organisations to promote and support the involvement of recreational fishers in all aspects of fish habitat management.

Objectives

- To collectively pursue national initiatives and activities related to improving fish abundance and biodiversity through habitat management.
- To share knowledge and support inter-jurisdictional collaboration.
- To make things happen on the ground in each jurisdiction across Australia.

Join us!

In Victoria, your Fish Habitat Network partners include VRFish, Fisheries Victoria and the Arthur Rylah Institute. We would love to hear from recreational fishers who are keen to learn more about fish habitat or are interested in habitat rehabilitation activities. There are opportunities to get involved throughout Victoria! Please contact Renae Ayres at the Arthur Rylah Institute on (03) 9450 8600 or renae.ayres@depi.vic.gov.au

For more information on the Fish Habitat Network, please visit www.fishhabitatnetwork.com.au, follow us on Facebook www.facebook.com/fishhabitatnetwork, or email us at fishhabitatnetwork@gmail.com. Sign-up for our e-newsletter *'Newstreams'* via the Fish Habitat Network website to keep up with the news, stories and information about fish habitat happenings in Australia and around the world.

Recreational fishers from New South Wales planting trees as part of the ongoing work to rehabilitate the Kooragang wetlands, near Newcastle. (Photo: Liz Baker)

Recreational fishing matters!

- About 3 - 5 million Australians fish each year (1, 2)
- Recreational fishing directly contributes an estimated $2.5 billion each year to the Australian economy (3)
- Recreational fishing supports 90,000 Australian jobs (2)
- Retail sales in the tackle and bait industry in 2003-04 was valued at $665 million (4)
- The recreational boating industry annual turnover related to fishing is around $300 million (2)
- International tourists spend over $200 million on fishing in Australia (2)

Fish matter!

- Up to 90 % of Australia's recreational fish spend part of their life cycle within estuaries and inshore wetlands (5)
- 50 % of Australian estuaries are in near-pristine condition, whilst 22 % are largely unmodified, 19% modified and 9% extensively modified (6)
- 86 % (161,764 km)of Australian rivers are degraded (6)
- Fish stocks in the Murray-Darling Basin are estimated to be at 10 % of pre-European levels (7)
- The total annual economic value of mangroves for fisheries, tourism and shore protection is estimated at ~ $US 900,000 per km^2 (8)
- 1 m^2 of seagrass adds 1 kg fish per year, equivalent to ~$A230,000 ha per year (9)

So what?

- Investment in fish habitat rehabilitation provides social, economic and environmental dividends
- Improving fish habitat will make more fish naturally and sustainably

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Habitat Habitat Habitat

by BOB PEARCE

Recreational fishers can often find things to disagree on and debate ad infinitum, but the one thing that we all seem to be in violent agreement on, is that if you want good, sustainable fishing, you must have good habitat.

Just ask VRFish Board Member, Rob "Woody" Loats. Whether it is fresh water, brackish, or salt water, the rules do not seem to change. However, this article concentrates on Port Phillip Bay.

According to a document prepared for the Fisheries Research and Development Corporation (FRDC), revitalising Australian estuaries will increase fisheries productivity and all aspects of coastal ecosystem biodiversity. The report indicates that any such investment in estuarine habitat would be recouped in increased fisheries in less than five years.

Much work has been done over recent years with re-snagging of rivers and artificial reefs in bays and estuaries. All seem to have been successful to one degree or another. More recently, however, it has become feasible to restore lost/degraded reefs more naturally. The ability to produce mussel and oyster spat to enable this is now well established at DEPI labs at Queenscliff.

As many would know, some parts of Port Phillip Bay that were once rich in shellfish reef structures, have become degraded in some cases, or completely eradicated in others. There are a variety of reasons for this, two of the main reasons being over exploitation and environmental degradation. Some of the over exploitation dates back as far as the 1870's, when oysters were being taken in large numbers by dredging activities. Large scale scallop and mussel dredging commenced on or about the mid 1960's and this also resulted in a lot of damage to shellfish reefs over a period of about 20 years.

As many would know, some parts of Port Phillip Bay that were once rich in shellfish reef structures, have become degraded in some cases, or completely eradicated in others.

Until the early 1980's, the reefs in Northern Port Phillip Bay were so abundant, that when a storm occurred, millions of mussels and oysters (mainly mussels) would be broken off the reefs and washed ashore. Because of the widespread reef degradation that has occurred, this phenomenon has not been evident for many years. While fishing for snapper on these reefs in the past, snag ups were common and would sometimes result in retrieving a clump of mussels and, perhaps, an oyster or two.

Albert Park Yachting and Angling Club (APYAC) has been working with DEPI/Fisheries Victoria for about two years on a project aimed at achieving the natural regrowing of reef areas with mussels and native oysters (ostrea angasi). The club's long established members have unique knowledge of the locations of many of the lost shellfish reefs of northern Port Phillip Bay, so are well placed to be able to assist with any project to rehabilitate lost reefs in the area.

Oyster reef restoration project in USA.

Industry operated shellfish culture facilities at DEPI Queenscliff.

In recent times, more and more people seem to have heard about this project and the club has received a great deal of encouragement and compliments about this initiative. There has even been interest from overseas, with the potential for assistance being offered in support for the project.

Currently, APYAC has a Grant Application with the Recreational Fishing Grants Working Group. If successful, the funding obtained would enable a trial to commence at three sites within Port Phillip Bay. Once the trial starts to show some promise, APYAC believes there is a strong chance that further funding would be attracted to expand the project. This is not a flippant prediction and is based on the amount of interest expressed in the project by other parties who are in a position to provide further funding. If the project is able to commence in the not too distant future, it would probably be the first such project in Australia.

A similar project at Chesapeake Bay, USA, has been highly successful and there will be opportunities to draw on the expertise of the managers of this project during the course of the Port Phillip Bay project.

APYAC have previously worked to get funding of $10,000.00 to enable some preliminary work on the project. A major outcome of this was a document prepared by DEPI's Dr Paul Hamer, entitled Towards reconstruction of the lost shellfish reefs of Port Phillip Bay. It is an excellent report and has under-pinned the ability to move into the next stage of the project. The report is highly recommended reading and is available from DEPI.

Although I am not in any way scientifically qualified, I feel safe in saying that the three critical rules that apply in enabling optimised bio diversity are: Rule 1, Habitat. Rule 2, Habitat and Rule 3, Habitat. That is what this project is all about.

We can all look forward to seeing this exciting project get under way in the not too distant future.

Recreational Fishing Code of Conduct

REPRESENTING
Victorian Recreational Fishers

A code of conduct for recreational boat, shore, river, stream and jetty fishers in Victoria.

Recreational fishers have a responsibility to look after fisheries resources for the benefit of the environment and future generations of fishers. Recreational fishers should also show respect for other users of the aquatic environment. This Code of Conduct provides guidelines to minimise conflicts on the water, and should be adopted by all recreational fishers.

1. Awareness of and compliance with fishing regulations

2. Respect the rights of other anglers and users

3. Protect the environment

4. Carefully return undersized, protected or unwanted catch back to the water

5. Fish species and other organisms must not be relocated/ transferred into other water bodies

6. Always seek permission when entering private property

7. Use established access roads and tracks

8. Attend to your fishing gear and value your catch

9. Education - pass on your knowledge

10. Respect indigenous sites and values

For a full version of the Code of Conduct, please go to
www.vrfish.com.au/Code_of_Conduct.htm

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Ph 03 9686 7077 **Fax** 03 9682 1066 **Email** info@vrfish.com.au **Web** www.vrfish.com.au

Instream Woody Habitat Assessment: *Our rivers need wood!*

By ZEB TONKIN

The 2012 winter edition of Fishing Lines featured the article "*Where is the wood? Mapping snags to benefit fish*" which highlighted a project being undertaken to prioritise river restoration programs aimed at improving river health and fish populations across Victoria.

This article presents the key findings of this project, highlighting many of our rivers fall well short of essential habitat to maintain stream health and support the sustainability of our all-important fish stocks.

A rehash on snags and the impact of their removal

Snags (instream woody habitat) play a vital role in a range of ecological, structural and chemical functions essential for maintaining the health of a waterway, and in turn support recreational fisheries and other social and cultural values.

In the past, snags were removed from many Victorian rivers for boating purposes, property protection and to facilitate flows. Research has since shown that their removal has minimal impact on flood mitigation, and that such works impair river stability and degrade river health. The removal of snags has been identified as a major contributing factor in the decline of many freshwater fish populations. River restoration programs help improve instream habitat and fish populations in Victorian rivers. These programs involve the re-introduction of wood (resnagging), and revegetating river banks to encourage long-term, natural snag input. To identify and prioritise areas where snags need protection and augmentation, baseline information on the level of wood in rivers is required.

The project

The Victorian Investment Framework funded this project in 2012 to help the Government prioritise the protection and rehabilitation of snags in Victorian rivers. Researchers from the Department of Environment and Primary Industries' (DEPI) Arthur Rylah Institute (ARI) have been working with Fisheries Victoria, Catchment Management Authorities, the University of Melbourne and Melbourne Water to investigate past and present snag densities in Victorian rivers.

We mapped snags in 38,000 river reaches across Victoria, equalling 27,700 km. Field assessments of natural snag densities were undertaken in "pristine" river reaches using hand-held GPS and underwater sonar. This information was used in a predictive modelling approach to determine natural snag densities in rivers across Victoria. Current densities of snags across Victoria were then calculated using a combination of high resolution aerial photographs, field assessments and measures of riparian overhang.

A simple comparison of the predicted natural and the current snag densities enabled researchers to assess the condition of snags in rivers throughout Victoria.

What were the findings?

The predicted natural snag densities in Victorian rivers were on average 0.03 m^3 / m^2 and varied according to slope, stream width and climatic variables. In general, natural snag densities were higher in lowland river reaches compared to upland river reaches, most likely a result of decreasing stream power. Current densities of snags in river reaches across Victoria are on average 0.01 m^3 / m^2 which equates to an average reduction of 41% below estimated natural levels.

Over 20,000 (53%) Victorian river reaches, equalling 17,000 km, have severely or highly depleted snags densities. 30% of river reaches were estimated to have snag densities more than 80% below natural levels.

Snag condition in some regions of Victoria fared better than others. The South Western Floodplains, Glenelg and North Central Floodplain river regions were in very poor condition (90%, 83% and

79% snag reductions respectively). The Alpine, North East Uplands and East Gippsland Uplands river regions displayed relatively minor variations from predicted natural snag densities.

What work will be done in the future?

Prioritising areas for resnagging is important, particularly to achieve best value for money. Managers are already using this broad-scale assessment to identify areas in most need of rehabilitation activities. Further refinement of these reaches should encompass site-specific, field-based assessments; consideration of river bank vegetation condition and; likelihood of ecological response to achieve a best "bang-for-buck" approach to resnagging. For example, the project team are currently investigating the relationship between snag loads and fish populations across Victoria. This will ultimately allow estimates of the levels of wood

The removal of snags has been identified as a major contributing factor in the decline of many freshwater fish populations.

required to maximise the benefits for particular fish species in a specific river reach. Research is also being undertaken to investigate the rates of natural accumulation of snags, and how this relates to the condition of river bank vegetation and bank stabilisation works.

For further information please contact Zeb Tonkin at the Arthur Rylah Institute on (03) 9450 8600

Anglesea River *instream habitat works*

Recreational fishers and the Anglesea River are set to benefit from a grant the Corangamite Catchment Management Authority (CMA) received through the State Government's $16 million Recreational Fishing Initiative.

The Corangamite CMA received the grant from the Department of Environment and Primary Industries (DEPI) to carry out works that will improve fish habitat for the long term health of the system.

The first stage of works has been completed, with the second stage to be finished during autumn. The works should help support higher numbers of fish in the estuary and assist in offsetting previous modifications to the river including the removal of snags.

This first stage completed before Christmas, involved placing limestone and small clumps of locally-sourced trees into deeper sections of the river, away from areas used for recreation.

Corangamite CMA Estuary Planning Coordinator, Tom Scarborough, said historical records indicated that snags had been removed from the river, which had resulted in the loss of important fish habitat.

Mr Scarborough said DEPI's Arthur Rylah Institute had completed sonar mapping of the river and provided the Corangamite CMA with a detailed report that included recommendations for improving in-stream habitat at key locations.

The Corangamite CMA is working in partnership with the Surf Coast Shire Council to ensure the instream habitat works are carried out safely and with minimum disruption along the river.

Signs will be placed at relevant locations explaining the works.

Creating Opportunities in the... Upper O

by ANDREW BRIGGS
Catchment Coordinator - Ovens & King

In 2010 the North East Catchment Management Authority commenced a project to improve recreational fishing in the Ovens River near Bright in North East Victoria.

Funded through the Recreational Fishing Licence program, the project aims were to install in-stream habitat structures (namely constructed hardwood log jams and bed seeding with large granite boulders), construction of a walking track for improved access and signage to increase awareness and inform the community of the project.

This particular reach of the Ovens River was drastically altered early in the last century by extensive gold dredging activity. This resulted in a stream with high volumes of mobile river gravels and very low levels of coarse habitat.

Coarse habitat is critical to fish populations for many reasons: it breaks up the current of the river, promotes scouring for deep pools, provides physical homes for fish, ambush sites for predatory species and velocity refuges for fish to retreat to in times of high flows.

This project enabled the North East CMA to showcase different approaches to introducing coarse habitat into a waterway. Over time, recreational fishers and river managers will be able to observe these structures and how they interact with the waterway.

Education was another key element of the project. In total over 2km of the Ovens River was divided up into four distinct runs, each one signposted and pitched at varying levels of competency.

vens River

Habitat, Access & Education

The first, "Jacks Run", combines detailed signage on when, where and how to fish, possible species to be encountered and explanations of the different types of habitat that have been created.

This reach has been specifically tailored to meet the needs of people who are new to fishing, or where future coaching clinics might be able to be carried out. The three other runs each contain a mix of natural and artificial habitats and walking tracks to help access the area.

This project was strongly supported by the Upper Ovens Landcare Group, who have carried out extensive woody weed management activities in the area, the Alpine Fly Fishers and the Council of Victorian Fly Fishing Clubs.

This particular reach of the Ovens River was drastically altered early in the last century by extensive gold dredging activity. This resulted in a stream with high volumes of mobile river gravels and very low levels of coarse habitat.

In 2013, this project was awarded the Council of Victorian Fly Fishing Club's Conversation Award. This award is given in recognition of the enhancement of waterways and impoundments with particular reference to riparian redevelopment, in stream habitat regeneration and foreshore protection.

VRFish Strategic Plan 2012–2017

COMMUNITY

Grow participation, membership and experience

- Ensure recreational fishing is promoted as a healthy and positive experience.
- Encourage greater participation from Culturally and Linguistically Diverse (CaLD) communities.
- Promote participation in recreational fishing to young people and families.
- Develop retention and recruitment strategies to grow the VRFish membership.

SUSTAINABILITY

Preserve, grow and enhance the fish resource, infrastructure and access

- Support sustainable fishing and fisheries through proactive and responsible policy development and projects.
- Work with fisheries management to identify opportunities for improvement and growth.
- Build on existing, and develop new conservation partnerships to enhance our role in supporting healthy, resilient recreational fisheries.
- Advocate for improved fishing infrastructure to support growth in recreational fishing.

AWARENESS

Strengthen and grow our communication and collaboration

- Ensure that the recreational fishing community are informed of issues that may impact on recreational fishing.
- Provide effective communication channels.
- Develop and refine engagement programs and activities across key communities.
- Provide sound advice and guidance on strategies and policies which will contribute to a sustainable future Victorian Fishery.

Five Key Pillars

The VRFish Strategic vision is supported by five key pillars and is underpinned by our core values. VRFish is committed to producing the following outcomes:

ACCOUNTABILITY

Ensure VRFish delivers best practice governance and management principles

- Improve our extension and adoption practices to be more accountable to recreational fishers.
- Support data collection and research that matches our organisational needs.
- Implement review process of governance structures.
- Report regularly to our stakeholders on our actions to ensure a sustainable and vibrant future fishery.

ADVOCACY

Provide effective representation of our members' interests

- Promote recreational fishing as a major contributor to economic growth in Victoria, particularly in rural and regional areas.
- Ensure VRFish members have appropriate best practice and educational resources.
- Influence policy and direction across all levels of government.
- Develop further recognition of VRFish as the legitimate conduit of recreational fishers.

VRFish
REPRESENTING
Victorian Recreational Fishers

VRFish Representing Your Interests

As the peak body representing a community of over 721,000 Victorians, VRFish works to provide fishers with support through facilitation, advocacy, education strategies and policy development. We consult broadly with the recreational fishing community to represent their views in an accurate and timely manner to Government and their agencies, as well as communicate effectively with the recreational fishers of Victoria.

VRFish Charter

...is to consult broadly with the recreational fishing community to represent the views of recreational fishers in an accurate and timely manner to Government and their agencies, as well as communicate effectively with the recreational fishers of Victoria.

VRFish Vision

...is to ensure full access to a diverse and healthy Victorian recreational fishery.

VRFish Mission

...is to represent and advocate the interests of the Victorian Recreational fishing community.

Going with the Flow

Undershot weirs like the one pictured may be killing large numbers of our native fish whilst they are still too small to see with the naked eye. (Photo: Craig Boys)

by MATT BARWICK

Recfishing Research

When Isaac Newton first said 'what comes up must come down' in the sixteen hundreds we all thought we was talking about apples. But perhaps he was talking about fish?

As fishers, we rely on our ability to anticipate where fish will be. In seeking to understand where freshwater fish go and why, most of us at one time or another have probably observed native fish aggregating below waterfalls/ weirs and other barriers, and worked out that certain cues trigger a desire to move upstream among many species.

Recfishing RESEARCH

The importance of these movements is now well established for a number of our freshwater fish species, enabling them to access spawning habitat, find food, and disperse to new areas. Many millions of dollars have been invested throughout Australia to construct fishways so fish can move past barriers such as dams and weirs as they travel upstream.

These fishways have proven to be fantastically effective too; up to 6000 juvenile fish were recorded moving upstream through a fishway on the Mary River in a single day. However researchers from NSW DPI are helping us to realize that we may only be addressing half of the problem, and it may be just as important that we ensure their safe passage downstream as well...

During a recent chat with Dr Craig Boys, a researcher from the NSW Department of Primary Industries, he explained, "The issue we face is that we have created a complex system of weirs, dams, irrigation pumps and hydropower facilities to provide a consistent supply of water and electricity for our communities. And unfortunately our studies are showing that they may be impacting on native fish trying to move downstream in a number of ways".

In the Murray-Darling Basin alone there are over 40,000 known barriers to fish movement. Many of these are what they call 'undershot weirs', which release water underneath steel gates as opposed to over a fixed crest. These weir designs have been shown to be particularly harmful to Golden Perch and Murray Cod: with a recent study estimating that as many as 95% of Golden Perch larvae and 52% of Murray Cod larvae are killed as they move downstream through these structures.

There are also irrigation pumps and canals along many of our rivers, and research undertaken by NSW DPI staff has shown that native fish are being sucked into them in very large numbers, and are either killed or transported into artificial waterbodies used for irrigation, unable to return to the river. This is a particular concern for young fish (eggs, larvae and juveniles), and particularly species such as Murray Cod, Golden Perch, Silver Perch and Trout Cod, which drift downstream as larvae after hatching, making them particularly vulnerable. Their drifting phase also coincides with peak irrigation periods (November and December).

Another emerging threat for fish moving downstream is hydropower facilities, which utilize water flow to turn large turbines, generating energy in the process. Unfortunately overseas examples are highlighting that these hydro facilities can seriously impact on fish travelling downstream, exposing them to dramatic changes in pressure (the equivalent of travelling from sea level to the top of Mount Everest in less than one second), risk of injury from hitting turbine blades or other solid components as fish are swept downstream, and exposure to violent shearing conditions when water rapidly changes speed or direction.

On the Columbia River approximately US$7 Billion has been spent attempting to prevent loss of migrating salmon in the region, however the impact of hydropower infrastructure on downstream-migrating fish has resulted in an ongoing reliance on hatcheries to bolster flagging populations. As both State and Federal Governments in Australia attempt to tackle climate change and meet their own renewable energy targets, hydropower is again being explored as a potential component of the future 'green' energy mix throughout Australia.

There is no doubt that many of our freshwater fish species are not doing too well; of the 46 native fish species in the Murray-Darling Basin, 26 (over half) are now listed as threatened under state or commonwealth legislation. Researchers have recorded larval Murray Cod from the lower Murray-Darling Basin during surveys (confirming spawning is occurring), but have failed to find one year old fish for the last 15-20 years. Where are these larvae disappearing to? Could our water infrastructure be contributing to this problem? It is generally accepted that the biggest losses have coincided with the rapid growth of water resource development and river regulation over the past century.

Many of our native fish species including the iconic Murray Cod undertake migrations up and downstream at various stages in their lifecycle. (Photo Jamin Forbes)

Where are these larvae disappearing to? Could our water infrastructure be contributing to this problem?

Whilst discussing these issues with Dr Boys he made the point "when you consider how much is spent annually on stocking programs, instream rehabilitation and the purchase of environmental water throughout Australia to support Australia's valuable recreational fisheries, it seems crazy that we continue to allow such large volumes of wild fish to be injured, killed and extracted needlessly every year. But the ray of light is that in most cases, there are practical solutions, which have proven effective elsewhere in the world, but have yet to be applied within Australia".

The irrigation sector has been proactive in working with NSW DPI researchers to establish the first design criteria for fish screens at water diversions within the Murray-Darling Basin. But unfortunately, although in a position to start rolling out pilot screening projects, there is currently no coordinated screening program or funding scheme to assist irrigators upgrade their diversions.

Fisheries managers are already working with river operators to promote the use of more conventional top spilling weir design (which are far less damaging to fish), rather than continuing with the construction of undershot weir designs. Research is also underway to determine the hydraulic conditions most conducive to fish survival at river infrastructure, with the view of designing more 'fish-friendly' options.

Fact Box:

- Many species of native fish, including Murray cod, Golden perch and Trout cod, drift downstream during their early life stages. They also undertake repeated downstream movements throughout their lives. This behaviour makes them vulnerable to injury or death when passing weirs, dams and irrigation diversions.
- Millions of larvae have been retrieved from individual irrigation canals and huge numbers (as many as 95%) of larvae can be killed when they pass downstream through weirs.
- There is currently no coordinated and funded screening program to prevent the loss of fish at water diversions in Australia, despite the fact that programs in North America have been hugely successful for close to a century.
- NSW DPI researchers are currently using state-of-the-art barometric chambers and swimming flumes to determine the hydraulic conditions required at dams, weirs and hydropower facilities to ensure the safe downstream passage of native fish.

If you have a question relating to science and recreational fishing simply email Recfishing Research at matt.barwick@recfishingresearch.org

Barotrauma injuries such as this air bubble within a 22 day-old Murray cod (below) and these bubbles in the dorsal fin of a 65 day old Murray cod (left) can result from rapid decompression experienced whilst passing through undershot weirs, or hydropower facilities, and can result in mortality. (Photo: Craig Boys)

Returning a Murray Cod collected during fish surveys back into the Ovens River.

by DR. SCOTT RAYMOND

Victorian Demonstration

...rehabilitating rivers to enhance native fish populations

History

Since European settlement, it's estimated that native fish populations in the Murray-Darling Basin (MDB) have declined by 90 percent. This decline is largely attributed to the removal of woody habitat 'snags' from rivers, damage to river-side (riparian) vegetation, river bank degradation, barriers to fish passage (such as dams and weirs), and impacts of introduced fish species (such as Common Carp).

To improve native fish populations in the MDB, a river restoration program known as a demonstration reach was developed through the Murray-Darling Basin Authorities' (MDBA) Native Fish Strategy. Demonstration reaches are stretches of river where a combination of river rehabilitation techniques are used to rebuild native fish communities. The demonstration reach program has three major components:

1. promoting community involvement;

2. initiating the rehabilitation works; and

3. monitoring the response of fish communities.

Victorian Demonstration Reaches

Two demonstration reaches were established in Victoria in 2007; on the Ovens River near Wangaratta and on Holland's Creek near Tatong. The Ovens River is home to the mighty Murray Cod and its endangered cousin the Trout Cod, while Holland's Creek is home to the elusive and endangered Macquarie Perch. Both waterways also contain a variety of small-bodied fish species integral to the structure and functioning of these ecosystems. In light of the difficulty of angling (and landing) a monster smelt, gudgeon or galaxiid, we will focus on the native large-bodied angling species in this article.

Getting started - Community

Partnering with various stakeholders commenced at the beginning of the program and was essential to demonstrate the value of working together to improve river health and foster ownership of the local environment. Community involvement was facilitated through community reference groups that included representatives from various local clubs and landholders.

Regular engagement events were held, including on-site meetings with school kids and program partners, participating in fishing and camping shows, and conducting electrofishing demonstrations. Signs were also installed along each demonstration reach to inform people about the project.

Project updates were communicated during face to face meetings, as well as more broadly on the internet, in the media, and at conferences.

Rehabilitation Works

The rehabilitation works programs were complex, large-scale, long-term investments conducted and managed by the North East and Goulburn Broken Catchment Management Authorities (CMA's). Over the seven year program from 2007 to 2014, multiple rehabilitation activities were undertaken in the Ovens River and Holland's Creek demonstration reaches for the purpose of enhancing the native fish communities, including:

- Re-introducing 350 large snags, 50 bank-shoring snags and 25 fish hotels to improve instream habitat
- Stocking 250 Macquarie Perch fingerlings into Holland's Creek
- Managing stock by erecting 20 km of fencing and providing 6 off-stream watering points
- Building and installing two fishways to improve fish passage
- Managing weeds along 30 km of river bank
- Stabilising river banks with 20 rock-seeding placements
- Planting 1000s of native trees and shrubs
- Removal of 1000s of Common Carp via carp musters, professional carp removal, other angling and community programs

Reaches

Monitoring fish responses

Electrofishing (boat and backpack) and fyke netting surveys were conducted annually between 2008 and 2014 by research scientists from the Arthur Rylah Institute for Environmental Research (ARI) to determine the impact of rehabilitation works on the abundance, distribution and population ecology of fish assemblages. Ten monitoring sites within each demonstration reach were surveyed before and after the rehabilitation works were implemented. These findings were compared with data collected from surveys on nearby control reaches to ensure the integrity of our data.

Inserting fish hotels into the Ovens River.

Holland's Creek Demonstration Reach sign.

Is river rehabilitation working? Yes!

There were several results which demonstrate an improvement in the fish community since the rehabilitation works were implemented in the Ovens River demonstration reach, as follows:

- A 4.6x increase in the abundance of Murray Cod
- A 2.7x increase in the abundance of Trout Cod
- Successful natural breeding of Trout Cod recorded for the first time in the reach since their stocking in the mid-90's
- A broader range of size classes in large-bodied native fish
- A change in the fish community from one dominated by introduced fish (such as Common Carp) to a healthier fish community dominated by large-bodied native fish.

Results from Holland's Creek demonstration reach are equally impressive:

- A 12x increase in the abundance of Macquarie Perch
- An increase in Macquarie Perch distribution in the demonstration reach
- First record of successful natural breeding Macquarie Perch in 2013 and again in 2014
- A decline in the abundance of introduced fish
- The demonstration reach is now dominated by native fish populations.

The success of the Ovens River and Holland's Creek demonstration reach programs was supported by a relationship between angling clubs, funding bodies, research scientists, CMA's, private consultants, environmental groups, land holders and the broader community. Over the seven year program, these groups came together to provide advice, concerns, interest and many lasting friendships have been developed. Fostering these relationships resulted in the clear relay of information, improved community interest and participation in the project, and understanding that this program was for the benefit of everyone.

Thanks are extended to all the individuals and groups that contributed to the resounding success of this and related projects that provide better fishing opportunities and healthier native fish populations for the future. This project was jointly funded by the MDBA, North East and Goulburn Broken CMA's and the Victorian Government's Recreational Fishing Licence Large Grants program.

If you would like more information about the Victorian Demonstration Reach program please contact Dr. Scott Raymond from ARI on (03) 9450 8600, or visit www.depi.vic.gov.au/ari

Recreational Fishers

= helping to improve fish habitat throughout Victoria

by RENAE AYRES

Arthur Rylah Institute

In a way, it's simple: healthy, productive fisheries need healthy, productive habitat. One of the simplest, most effective things we can do to support great recreational fisheries is help create healthy habitat. Yet there's also a lot of complexity in what healthy habitat really means.

Australian recreational fishers are increasingly becoming better informed about what constitutes healthy habitat. We know that healthy fish habitat includes diverse and complex structures in and around the water, good water quality, and the right water flow regimes.

Australian recreational fishers are also becoming more active as advocates for improving fish habitat. In a 2009 survey, recreational fishing licence holders in Victoria acknowledged that 'repairing where fish live' was the most important way to improve recreational fishing. In 2012, Fisheries Victoria conducted a subsequent survey and asked fishers about their preferred fishing locations, catch species and suggestions for improving habitat. Many people indicated they were interested in participating in projects to improve habitat.

Some Victorian recreational fishers and angling clubs are already actively involved in projects working to improve fish habitat and the health of local fish populations. For example, the Nicholson Angling Club has taken on projects along the Nicholson River over several years, fencing river frontage to manage stock access, revegetating riverbanks with native trees, installing instream woody habitat (snags), and monitoring water quality under the Waterwatch program. Also, the Alpine Fly Fishing Club and Council of Victorian Fly Fishing Clubs partnered with the North East Catchment Management Authority and Upper Ovens Landcare Group to rehabilitate instream habitat and riverbanks of the Ovens River near Bright to support popular angling species including Murray cod and trout. There are many other examples of recreational fishers playing a significant role in habitat rehabilitation projects. The success of such projects stems from people sharing a passion for healthy local fisheries and environments, and working together to achieve a common goal.

Recreational fishers are encouraged to support and participate in other similar projects across Victoria. Here are some current ways you can get involved!

Native revegetation along shores of the Hopkins River estuary has helped improve habitat for fish. (Photo: Glenelg Hopkins Catchment Management Authority)

Improvements to the fishway at Wangaratta has aided passage of Murray cod and other fish.

(Photo: Scott Raymond)

UNDERSTANDING Fish Habitat
More Habitat = More Fish

Anglers on Estuaries:

There are opportunities for recreational fishers to get involved in fish habitat rehabilitation activities planned for the estuaries of the Merri River, Gellibrand River, Werribee River, Tarwin River, and Mitchell, Nicholson or Snowy River. This work is part of a broader collaborative project undertaken by the Arthur Rylah Institute (ARI) together with VRFish, Australian Trout Foundation, Native Fish Australia, Fisheries Victoria, coastal Catchment Management Authorities, Melbourne Water, the Fish Habitat Network, and the Department of Environment, through funding from the Australian Government, Fisheries Revenue Allocation Committee, and in-kind contributions. Likely activities include: installing in-stream habitat, revegetating riverbanks, weed management, and improving fish passage. There will also be education and engagement events. Any local recreational fishers and clubs keen to be involved please contact, Renae Ayres at ARI on (03) 9450 8600.

Victorian F4FH:

The Victorian Fishers for Fish Habitat (F4FH) Program enables Victorian recreational fishers to get more actively involved in fish habitat rehabilitation. The program aims to: raise awareness of the Fish Habitat Network and the critical role of fish habitat; facilitate collaboration between recreational fishing organisations, Fisheries Victoria and other government agencies (e.g. Catchment Management Authorities) on fish habitat projects; and encourage fisher involvement in on-ground actions to improve fish habitat. ARI researchers, who lead the project, deliver presentations at community events and angling club meetings about the importance of healthy fish habitats and local fish research projects, and have helped waterway managers and angling clubs prepare funding applications for habitat rehabilitation. The project is funded by the Victorian Government using recreational fishing licence fees with support from VRFish, the Australian Trout Foundation and Native Fish Australia. Again, contact Renae Ayres at ARI on (03) 9450 8600 if you'd like to be involved.

Regional Waterway Strategies:

Victorian Catchment Management Authorities undertake strategic planning, on-ground works and monitoring programs to manage and improve waterways, and they are keen for community participation. Currently, Catchment Management Authorities are renewing their regional waterway strategies that outline regional approach for river, estuary and wetland management for the next eight years. Recreational fishers have been involved by recommending regional fisheries management priorities relating to protecting key fisheries assets and fish habitat recovery works. The public consultation phases for the draft regional waterway strategies invite recreational fishers to have further input and comment. There is clearly mutual benefit in working together on fish habitat projects that lead to better fishing outcomes. To get involved or provide feedback, please contact your local Catchment Management Authority.

Grants:

Each year, the Victorian Recreational Fishing Licence Grants Program funds projects that help improve recreational fishing in Victoria, including habitat improvements. Recreational angling clubs have successfully received funding through this program in the past, often working with regional waterway managers and community groups on habitat projects. To learn more, please visit www.depi.vic.gov.au/fishinggrants.

The Victorian Government's Communities for Nature grants support the Victorian community to contribute to practical on-ground solutions for local environmental issues. Funds are provided for projects that address, for example, revegetation, weed and pest animal control, threatened species recovery, cleaning up waterways (e.g. fencing, replacing logs in stream, constructing fishways, etc.). To learn more, please visit www.depi.vic.gov.au/c4n

Catchment Management Authorities and Councils/Shires may also offer similar natural resource grants.

Recreational fishers can actively support fish habitat and healthy fish populations by getting involved in, or supporting, any of the programs above. Other simple things which recreational fishers can also do include: looking after existing habitat, advocating for habitat, and teaching new fishers about the importance of fish habitat.

For more information, please contact Renae Ayres at ARI on (03) 9450 8600, or visit www.depi.vic.gov.au/ari

EstuaryWatch *know what's taking the bait*

by ROSE HERBEN
Victorian EstuaryWatch Coordinator

Spring Creek EstuaryWatchers.

Local knowledge helps fishers discover what's biting, and chatting to your local **EstuaryWatch** volunteer is a great way to find out what's taking the bait.

The Anglesea EstuaryWatch group, one of the four pilot groups established in 2007, love sharing what they know about the river with people they chat to when they're out monitoring.

EstuaryWatchers conduct monitoring when an estuary opens or closes to the sea, after heavy rainfall and storm surges, and capture low pH events caused by acid sulphate soils. The volunteers receive training and support from an EstuaryWatch Coordinator, and with the knowledge gained from their monthly monitoring they're able to share their knowledge with people they chat with along the river.

And volunteers said the best conversations were with fisher people and sharing information about what fish are biting.

Anglesea EstuaryWatch Team Leader Gabriel Fuller said what excited her most about EstuaryWatch was getting outdoors and being part of a quality local community environment study.

EstuaryWatch was initiated as part of the Large Scale River Restoration Initiative - Managing Our Great Ocean Road Estuaries at Corangamite Catchment Management Authority (CMA). The program's guiding vision is to:

- Raise awareness and provide educational opportunities to the community in estuarine environments
- Enable communities and stakeholders to better inform decision making on estuary health.

An estuary is the place where freshwater from a river mixes with salt water from the sea. Estuaries are a great spot to spend time fishing, swimming, walking, canoeing, or having a picnic with friends and family. Importantly they also act as a nursery for a variety of fish and provide essential food and habitat for birds and other wild life.

Three other EstuaryWatch groups were established as part of the Corangamite CMA pilot program at the Gellibrand River in Princetown, Painkalac Creek in Aireys Inlet and Spring Creek in Torquay. This included developing a framework for community monitoring of estuaries and involved volunteers, staff and Deakin University. Following the success of the Corangamite CMA pilot the program expanded in 2010 and there are now active EstuaryWatch volunteers, supported by EstuaryWatch Coordinators at Glenelg Hopkins CMA, West Gippsland CMA and Melbourne Water.

Wye River EstuaryWatchers.

There are 19 active EstuaryWatch groups in Victoria. They meet monthly to conduct estuary mouth condition monitoring and physical/chemical monitoring. Estuary mouth condition monitoring involves taking a series of referenced photos at the estuary mouth, recording mouth state (open or closed), wind direction, wind strength, sea state, tides and estuary water level.

On average there are four physical/chemical monitoring sites on an estuary. At each site volunteers record important indicators of estuary health such as dissolved oxygen concentration, temperature, salinity, pH and turbidity at depth. Salinity records taken along the length of the estuary can help determine the extent of a salt wedge and can give an indication of what species of fish are likely to inhabit the estuary at any point in time.

The data volunteers collect has proven to be a valuable source of information for river health staff managing waterways. The data volunteers collect is often referred to in regions of Victoria where the Estuary Entrance Management Support System has been adopted to assist waterway managers in determining when an estuary is artificially opened to the sea.

Corangamite CMA Estuary Planning Coordinator Tom Scarborough refers to the EstuaryWatch Online database daily. EstuaryWatchers work closely with waterway managers keeping them informed of river health works on their estuary and the role waterway managers and land managers have in conserving their estuary. This includes works that will improve fish habitat like work improving the health of the Anglesea River system.

All of the information collected by EstuaryWatch volunteers is available to the public at www.estuarywatch.com.au.

Feel free to take a look next time you are thinking of throwing a line in at your local estuary. Regional EstuaryWatch programs host community seminars, workshops and field trips throughout the year on Victoria's estuaries.

If you'd like to know about upcoming events or are interested in becoming an EstuaryWatch volunteer please contact Rose Herben, EstuaryWatch Coordinator estuarywatch@ccma.vic.gov.au

Tackling Climate Change

by MATT BARWICK
Recfishing Research

If you live in eastern Australia you have probably been shaking your head at the weather we have been experiencing over the last couple of months, and wondering if it's a sign of things to come. Whether a result of climate change or just intense weather, there's no doubt that the incredible rainfalls, waterspouts, phenomenal seas and strong winds in recent months have made it difficult to wet a line at times.

Climate change is definitely starting to impact on our marine systems in a number of ways; researchers have reported that sea surface temperatures off Maria Island in southeastern Australia have increased by 1.5°C since the 1950s, and that sea levels have continued to rise at a rate of 1.7 ± 0.3mm per year during the 20th century. The pH of seawater has also been noted to drop by 0.1 units since the industrial revolution.

These and other environmental changes appear to be causing shifts in populations of some species, with consequent affects on the ecosystems they inhabit. For example, a combination of strengthening of windspeed and the East Australian Current in the Southern Ocean may be resulting in the range extension of the long-spined sea urchin Centrostephanus rogersii, which previously was not known to be common in Tasmanian waters, but is now creating expansive urchin barrens, or areas grazed so heavily by these voracious urchins that practically nothing else can live there.

So exactly how will climate change impact on recreational fishing in Australia? Will it all be bad news? Or will there be some opportunities created by a changing climate? And how should we adapt to climate change?

A study funded under the National Recreational Fishing Industry Development Strategy has been looking into these questions to help the fishing community to adapt to the impacts of climate change, and mitigate their contribution to climate change by reducing carbon emissions through changing their practices.

The study has revealed that for recreational fishers, climate change may bring about changes in fisher satisfaction (both in terms of catch and experience), which may result from changes in catch or quality in fishing experience. This, in turn may cause changes to participation levels, and/or expenditure over time.

Many of the human variables associated with a changing climate are difficult to quantify as it can be difficult to determine how people will behave. However we can look at the biology of fish species that we target and get an understanding of how they might respond.

Project team members examined likely impacts for important recreational species in northern, south-east and western Australia regions separately. Black Bream was considered vulnerable to climate change impacts as a predicted change in the frequency and intensity of rainfall events is expected to present less ideal conditions for spawning and recruitment of this species.

Roe's Abalone was also considered vulnerable to climate change in the Western region as the species spends most of its life in shallow water on reef top habitat, and so may be exposed to extreme heat waves, with increased mortality resulting. Other species such as Mangrove Jack and Dusky Flathead in the Northern Region and Yellowtail Kingfish and Mahi Mahi in the South-East region were considered fairly resilient to climate change impacts (*see table below for a full account of likely risks*).

So what can we do to adapt and/or mitigate impacts of climate change? Well, the study identified a need for good quality data to enable future trends in fishery productivity to be predicted. Anglers can play a role in collecting this data through getting involved in angler diary and tagging programs. The research team also highlighted the need for managers to start managing fish populations as an entire stock, rather than breaking them up by jurisdictional boundaries (which fish don't abide by). The need was also highlighted to look for ways to make bag and size limits more flexible, to respond to increasing/decreasing fishery productivity as rainfall and nutrient levels fluctuate.

Unfortunately we currently don't have an understanding of the contribution of recreational fishing to greenhouse emissions, or whether emissions from rec fishers are increasing or decreasing. Nevertheless, there are opportunities for the fishing community to contribute to reductions in emissions through moving to lower emission and more fuel efficient outboards and adoption of methods with minimal emissions such as use of kayaks, shore-based fishing etc.

In terms of mitigation, researchers highlighted that repairing our coastal ecosystems provides the greatest potential benefits, as seagrasses, mangroves and salt marshes are the highest per hectare carbon sequesters of all Australian landscapes. More abundant healthy habitat would also offer the added benefit of helping to increase resilience of the populations of fish species that we target as well.

Further Reading:

http://eprints.utas.edu.au/6290/

http://www.climatechange.gov.au/publications/fisheries/fisheries.aspx

Research indicates that Black Bream (below) might be in trouble under a changing climate, but Dusky Flathead (above) are expected to be resilient. (Photos: Matt Daniel)

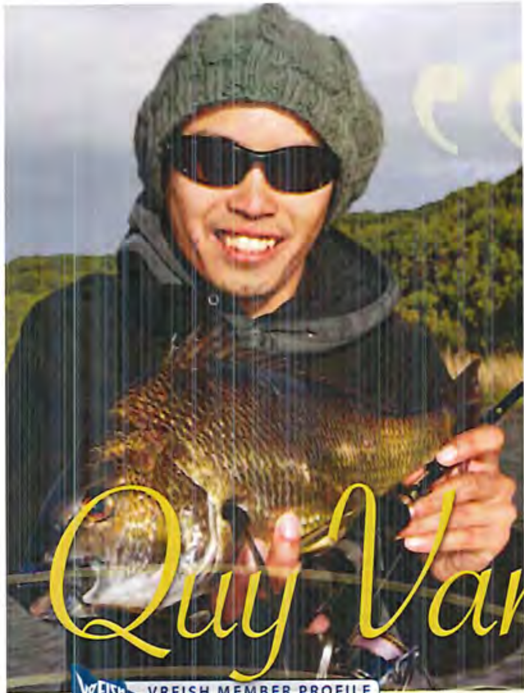
Northern region	South East region	Western region
Mangrove Jack (Lutjanus argentimaculatus)	Black Bream (Acanthopagrus butcheri)	West Australian Dhufish (Glaucosoma herbaicum)
Spotted Mackerel (Scomberomorus munroi)	King George Whiting (Sillaginodes puntatus)	Baldchin Groper (Cheorodon rubescens)
Red Emperor (Lutjanus sebae)	Mahi Mahi (Coryphaena hippurus)	King George Whiting (Sillaginodes puntatus)
Barred Javelin (Pomadasys kaakan)	Yellowtail Kingfish (Seriola lalandi)	Spanish Mackerel (Scomberomerus commerson)
Dusky Flathead (Platycephalus fuscus)		Australian Salmon (Arripis truttaceus)
		Roe's Abalone (haliotis roei)

KEY

Considered to be resilient to climate change

Vulnerability to climate change uncertain

Considered to be vulnerable to climate change



Quy Van

VRFISH MEMBER PROFILE

From my first time catching a pilchard, which was in turn bait for a kingfish ... I learnt about the food chain, the oceans bounty and how we should respect it.

From a boy of a very young age, I have had fishing and diving ingrained into me. I am a very keen recreational angler and diver who is a sucker for catching anything from a garfish right up to game species like southern blue fin tuna, marlin and everything else in-between, with the odd crayfish thrown in.

Whether it be fresh water, saltwater or estuarine fishing, I don't discriminate. It is no secret that I skimped out on exams and classes during my time at Deakin University to go fishing because the "tuna" were on, or the "seas are pancake flat" and went fishing or diving instead…priorities!!

My passion for the ocean started when my family moved to New Zealand, along the picturesque coastline of the Bay of Plenty. Being allowed to explore the ocean at my free will through diving and playing rock pools as a curious boy, along with a father who also lived and breathed fishing – for survival and nowadays recreation – has permanently embedded a strong infatuation of the ocean into me.

I owe it to my father for his excellent guidance and introduction to fishing. From my first time catching a pilchard, which was in turn bait for a kingfish (which was in turn consumed by my family) it was on this very day I learnt about the food chain, the oceans bounty and how we should respect it.

I have worked in the tackle retail industry for six or so years and I have seen many trends in recreational fishing come and go. Due to my geographical location (South West Victoria, Warrnambool and surroundings) I am living in a "poor man's paradise!". There are many fishing and diving options here and I predominantly chase the charismatic estuary perch, black bream and sea run trout, with the occasional cray dive when weather permits.

Originally, I started out my career as a nurse, with the plans to travel and work as a nurse, and fish along the way. However, my passion and obsession for recreational fisheries and the marine environment lead me to do a degree in environmental science (marine biology), with a focus on fisheries management and recreational fisheries, and further progressing to do an honours research year focusing my study on the physiological stress levels in a key Victorian recreational fish species (black bream) from capture and confinement – as it is becoming common practice to live hold and release fish after tournament fishing as well as recreational fishing for black bream.

With my strong desire to enhance recreational fisheries, I look forward working with VRFish.

April Vokey

PROMOTING PARTICIPATION FOR **WOMEN & CHILDREN**

April Vokey has agreed to assist VRFish in its quest to increase fishing participation rates amongst women and children. April has extensive international experience in implementing engagement and participation strategy models for women in recreational fishing. Whilst there are some programs in place to teach children how to fish in Victoria and NSW, there is nothing in place to address the current issue that fishing is largely a male dominated activity.

April shares her time between British Columbia and Sydney, Australia, and is an avid angler and steelhead, salmon and trout guide. She was born with an unexplainable passion for fishing. As a young girl she coaxed her father into going fishing and by the age of sixteen, when she was old enough to drive, she was devoting all of her free time to her local rivers.

She is passionate about Spey casting to wild steelhead, the environment and tying Salmon/Steelhead flies. She has made it her mission to encourage and introduce aspiring anglers to the sport, in hopes that it will bring them as much pleasure as it has brought her. She takes pride in being an eternal student of fly-fishing and an active conservationist.

In 2007 she founded B.C. based guiding operation, Fly Gal Ventures, where she presently guides and instructs anglers on some of B.C.'s best steelhead destinations. Fly Gal's trips and events can be found at www.flygal.ca.

April is a Federation of Fly Fishers Certified Casting Instructor and fly-fishing columnist. She is a member of the Northwest Outdoor Writers Association and is the Canadian field editor for *Chasing Silver* magazine and the steelhead columnist for *Fly Fusion* magazine. Her works and photos can also be found in *Fly Fisherman Magazine, Salmon Trout Steelheader* (STS), *Field and Stream, Canadian Fly Fisher, Flyfishing and Tying Journal* and several other international publications.

April sits on the board of directors for the Steelhead Society of BC and the BC Federation of Fly Fishers.

She is the founder and director of the popular fundraiser, Flies for Fins (www.flies4fins.com), and in 2011 she proudly joined the Patagonia ambassador team, where she continues to assist in the design and direction of an upcoming women's line of fishing apparel.

VRFish is looking to commission a credible scoping study to:

- identify the current barriers and constraints;
- identify current drivers and opportunities; and
- develop an action plan for the future.

The study would examine international case studies and draw on the successes in places such as Canada and USA. The project would also run a scoping workshop with relevant stakeholders to help develop the action plan and form an advisory group, made up of female anglers, would provide a lasting legacy from the project and give women who fish, of all ages and backgrounds, a voice at fishing roundtables, state councils and discussion groups and serve as a focal point for growing participation.

VRFish is thrilled to have April's expertise on board as we unearth this exciting initiative.

Fishing in Victoria – something for everyone

Victorian fishers are a blessed lot – the fisheries across the State provide ample opportunities to ply your skill and feed your family.

Over 721,000 Victorians share a passion for recreational fishing, and there are fishing clubs scattered all over the State catering to fishers whether they be hooked on feeding 'old man' cod or like to chase the big reds as they come into our bays to spawn.

There are many reasons a large segment of VRFish members belong to fishing clubs:

> Fishing clubs give fishers access to a fantastic group of people who love to talk about fishing as much as they do.

> They give a sense of contributing to the local community.

> Club membership provides an opportunity to participate in social and competitive events.

> They give the ability to improve fishing by learning from more experienced fishers or to share your own knowledge.

> Club membership also provides a means to contribute to the political landscape of fishing, and have your say in issues that affect you and your favourite fisheries.

Contact one of our member clubs opposite for more information.

Member directory

Albert Park Yachting & Angling Clubs Association
Contact: Patrick Hutchinson
Phone: 03 9329 8200
Email: info@apyac.org.au
Web: apyac.org.au

Association of Geelong & District Angling Clubs
Contact: John Hotchin
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Web: fishinggeelong.com

Australian Anglers Association (VIC)
Contact: Tim Hose
Phone: 0428 521 449
Web: aaavic.org

Australian National Sportfishing Association (VIC)
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Beaumaris Motor Yacht Squadron
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Web: fishcare.org.au

Game Fishing Association of Victoria
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Goulburn Valley Association of Angling Clubs
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Email: wcubbin@bigpond.net.au

Howqua Angling Clubs Fish Protection Association
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Midland & North Central Angling Association
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Email: gregh.ogp@hotmail.com

Mid Northern Association of Angling Clubs
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Native Fish Australia
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Web: nativefish.asn.au

North East Angling Association
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Scuba Divers Federation of Victoria
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South West District
Association of Angling Clubs
Contact: Gary Cronin
Phone: 0417 125 127
Email: gbear@hotmail.com

Southern Freedivers
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Email: info@brimbosports.com
Web: southernfreedivers.org.au

Torquay Angling Club
Contact: Steve Burton
Phone: 0412 101 225
Email: fishing@torquayfish.com.au
Web: www.torquayfish.com.au

Victorian Fishing Charters Association
Contact: John Willis
Phone: 0407 053 484
Email: john@beachmarine.com.au

Victorian Piscatorial Council
Contact: Peter Milley
Phone: 0419 537 082
Email: pmilley@bigpond.net.au

Wimmera Anglers Association
Contact: Barry Williams
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Email: barry3422@bigpond.net.au

Revitalising Australia's Estuaries

- multiple benefits if we can meet the challenges of turning the tide on past mistakes

Estuaries & wetlands repair – key to productivity

Clarence River – 2013 Flood Event:

Everything dead - benthic sampling from Grafton [below tidal limit] to ocean [some 90 river km downstream at Yamba].

This image – de-oxygenation and acidic effluent from drained wetlands killed all worms generally found in sediments

Estuaries & wetlands repair

– key to Australia's productivity with multiple benefits

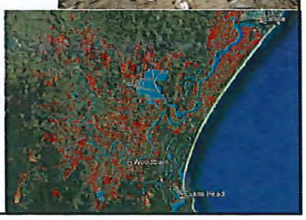
* Jobs
* Lifestyle
* Biodiversity
* Food security
* Balance of trade
* Health

But……how do we gain investment?

5 key messages

1. **Fisheries productivity** - our resource has markedly declined
2. **Change in our estuaries** – the next generation do not realise what is gone
3. **Understanding the repair opportunity** – our policy makers and advisors and community lack understanding of the opportunity
4. **Fisheries management** – time to understand the causes of productivity decline are NOT fishing
5. **Focus** – we need to capture the public's imagination with some clear sucesses

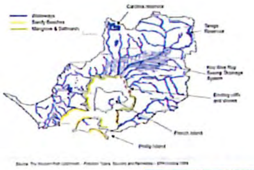




1 Fisheries Productivity e.g. - Richmond floodplain – massively drained for low value grazing



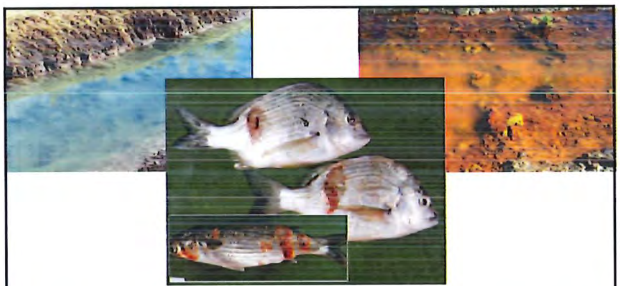
NSW – the basket case in wetland drainage and acidic deoxygenated effluent


2 Change - e.g.Westernport, Vic

3 Opportunities - thematic repair priorities

* **Restoring connectivity and fish passage –** barrages, blocks, inadequate culverts, causeways
* **Restoring estuary processes –** especially tidal and freshwater flows and fluxes, ph and oxygenation
* **Repairing drained floodplain wetlands –** removing or manipulating barrages to allow tidal water and wetland recovery and reshaping landforms to remove drains and levees, especially for acid sulphate
* **Re-establishing mussel and oyster reefs -** key within-estuary nursery through to adult fishery habitat as well as performing a water quality improvement function
* **Re-establishing seagrasses –** replanting of initial re-colonizers especially in the SA gulfs and the provision of seagrass friendly moorings



- Repair the wetlands to minimize fish disease and oyster deaths


Big Swamp, Manning – pollution could be fish production


***Floodgate and drain removal Clarence floodplain* – soil carbon + biodiversity + productivity + fishery + water quality**

Business as usual is drained poorly productive wetlands.....

- Levees, drains, algae & de-oxygenation – how to start a "black water event", a fish and prawn kill .....OR ...trash the levee.

Acquisition + Repair - Everlasting Swamp & Sportman's Creek

- Tidal flow repair e.g. Shallow Channel, Clarence

❑2 box culverts

❑ Green slime and mud to sand spits, high tidal flow and fast food zone

Shallow Channel, Clarence

Seagrass repair

Example: "crop circles" around moorings

Incentives for transition to seagrass friendly moorings and then regulate

4 Fisheries Management

1. Over 70% of our commercial catch species have an estuary dependent phase – CPUE is not reflecting the main threats to our inshore fisheries; habitat loss, not effort is driving down population abundance

2. Probably 80% to 90% of recreational catch is estuary dependent – estuary fisheries provide for the Australian lifestyle...with over 3.4M Australians recreational fishers

3. Marine parks are less than optimum without fish! – time to also take an ecosystem approach to marine biodiversity conservation

4. Multiple other benefits – flood control, waterbirds, biodiversity, buffering, water quality, carbon sequestration

RESOURCE ALLOCATION – After we enhance productivity

5 Focus – my thoughts for VRFish

My suggested criteria -

1. A major project, large in scale, preferably in an urban area to capture public support and media attention

2. Need multi-partners across public and private sectors - contributing $ and commitment

3. Project should lead to major productivity improvements in an iconic fishery

4. High likelihood of success and low risk

5. Politically benefiting multiple electorates / bi-partisan support

Within Estuary Repair - If oyster and mussel reefs were the Great Barrier Reef...."functionally extinct"

Oyster and mussel reefs –

within estuary multi-dimensional habitat and purification systems

e.g. basis to re-establish Port Phillip snapper fishery

Next Steps – a discussion

-

1 - Massive losses in productivity

2 - Changes to resource now almost forgotten

3 - Poor understanding of repair opportunities

4 - Fisheries management needs a re-think

5 - Focus to demonstrate the benefits

Estuaries & wetlands repair – key to productivity

Project materials developed

Science community

- **Journal of Marine and Freshwater Research 2015**– *Repairing Australia's estuaries for improved fisheries production – what benefits at what cost?* Creighton, Boon, Brookes and Sheaves.

- **Ecosystems** – submitted – *Adapting management of marine environments to a changing climate – a checklist to guide reform and assess progress* Creighton, Hobday, Lockwood and Pecl

- Australian Society of Fisheries Biology *Revitalising Australia's Estuaries* [Abstract and PowerPoint]

- Australian Society of Fisheries Biology *Rethinking fisheries management – responding to a changing climate, habitat loss and community pressures* [Abstract and PowerPoint]

- National Marine Science Symposium - *R&D Priorities – Australia's estuaries, embayments and nearshore marine environments* Colin Creighton, Paul I. Boon, Justin D. Brookes, Marcus Sheaves, Patricia von Baumgarten , Fiona Valesini , Dr Frederieke Kroon and Dr Greg Ferguson

- National Estuary Network *Revitalising Australia's Estuaries - - multiple benefits if we can meet the challenges of turning the tide on past mistakes* [PowerPoint]

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Repairing Australia's estuaries for improved fisheries production – what benefits, at what cost?

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Abstract. An Australia-wide assessment of ~1000 estuaries and embayments undertaken by the National Land and Water Resources Audit of 1997–2002 indicated that ~30% were modified to some degree. The most highly degraded were in New South Wales, where ~40% were classified as 'extensively modified' and <10% were 'near pristine'. Since that review, urban populations have continued to grow rapidly, and increasing pressures for industrial and agricultural development in the coastal zone have resulted in ongoing degradation of Australia's estuaries and embayments. This degradation has had serious effects on biodiversity, and commercial and recreational fishing. A business case is developed that shows that an Australia-wide investment of AU$350 million into repair will be returned in less than 5 years. This return is merely from improved productivity of commercial fisheries of a limited number of fish, shellfish and crustacean species. Estuary repair represents an outstanding return on investment, possibly far greater than most of Australia's previous environmental repair initiatives and with clearly demonstrated outcomes across the Australian food and services economies.

Additional keywords: biodiversity, coasts, embayments, repair.

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Introduction

The National Land and Water Resources Audit of 1997–2002 included the most comprehensive and nation-wide assessment of the condition of coastal aquatic systems yet undertaken in Australia. It adopted a broad definition of the term 'estuary', orientated towards human use and management: estuaries were defined as all semi-enclosed coastal water bodies where marine water from the ocean mixed with fresh water draining from the land, or any coastal environment where marine and fluvial sediments occurred together (National Land and Water Resources Audit 2002). This management-orientated definition is much broader than the long-standing and widely accepted biophysical definition of an estuary as 'a body of water in which river water mixes with and measurably dilutes sea water' (e.g. Reid 1961; Hodgkin 1994). Nevertheless, the Audit's definition is useful in the present context because of its wider scope and because it encompasses important coastal systems that would not be considered estuaries under the more conventional definition: Corner Inlet, Port Phillip Bay and Port Jackson are examples. Information was collected by the Audit on 974 coastal water bodies, of which, on a nation-wide scale, 9% were assessed as being 'extensively modified', 19% as 'modified', 22%, largely unmodified' and 50% 'near pristine'. Globally, Jackson *et al.* (2001) stated that estuaries are among the most degraded of all marine ecosystems.

In the ~15 years since the Australian Audit was undertaken, coastal populations have continued to grow at rates that exceed those of inland Australia, with particularly rapid growth occurring in northern New South Wales, south-eastern Queensland and south-western Western Australia (Australian Bureau of Statistics 2010). This population growth and the associated processes of spreading urbanisation, industrial development and agricultural development together place intense pressures on the ecological integrity, biodiversity, and natural and cultural heritage of coastal aquatic environments, and particularly on estuaries.

These processes are increasingly reflected in the ongoing trend of degradation of Australia's estuaries and the loss of fish habitat, of seagrass-beds, mangroves, saltmarshes and fresh to brackish sedge and paperbark floodplain wetlands. In turn, this loss of habitat is associated with changes in fishery catches and there is now abundant evidence that Australia is progressively

losing commercial and recreational fisheries on a nation-wide scale. Fishery resources are important for high value secure food supply and for the recreational and indigenous fishing sectors and also have ramifications from lifestyle and tourism perspectives (e.g. Smith 1981; Creighton 1982; Skilleter and Loneragan 2007).

Specific quantitative information on the loss of critical habitat is also available from several habitat- or region-specific studies to expand on the Audit's Australia-wide assessment. Saintilan and Williams (2000), for example, reviewed the record of loss of coastal saltmarsh in eastern Australia since World War 2, and reported losses as 100% for parts of Botany Bay, New South Wales, over the period 1950–1994 and 67% for the Hunter River (excluding Hexham) from 1954 to 1994. Harty and Cheng (2003) reported a loss of 78% of saltmarshes in Brisbane Water, near Gosford, New South Wales, between 1954 and 1995. Sinclair and Boon (2012) showed that the State-wide loss of coastal wetlands (mainly mangroves and saltmarsh) in Victoria since European colonisation has been variously 5–20% by area across the State, with the greatest losses occurring in heavily urbanised areas such as around Port Phillip Bay (~50% loss) and in agriculturally developed regions such as Gippsland (e.g. 60% loss from Anderson Inlet in South Gippsland). The threats facing the remaining coastal wetlands are diverse and extensive (Boon *et al.* 2014). Losses of seagrass beds have been reported for Western Australia (Walker 2003) and eastern Australia (Coles *et al.* 2003), the latter assessment recording the loss of 450 km^2 of seagrass bed in recent years, largely attributable to eutrophication, natural storm events, and reductions in light availability as a result of coastal development and increased sediment input. Johnson *et al.* (1999), building on unpublished mapping work by Russell and Hale of Queensland Fisheries, found that for Great Barrier Reef floodplains, such as on the Herbert River, more than 80% of fresh-to-brackish water wetlands had been cleared and drained. The mapping also found slight increases in the area of mangrove-dominated wetlands, which was attributed to increased sedimentation, especially of prior sandy shallow waters and seagrass beds (see also Waycott *et al.* 2009).

Micro-tidal systems are particularly prone to extreme eutrophication and thus hypoxia, which is clearly a major problem in many estuaries in southern Australia with their limited tidal range and often alterations to tidal flow that has accompanied development (e.g. Diaz 2002; Vaquer-Sunyer and Duarte 2008). Indeed, Diaz (2002) stated 'no other environmental variable of such ecological importance to estuarine and coastal ecosystems around the world has changed so dramatically, in such a short period of time, as dissolved oxygen'. He goes on to state that this threatens the 'loss of fisheries and biodiversity and alteration of food webs in these systems'.

The declining condition of coastal environments across much of Australia has been documented also in *State of the Environment* reports, commencing with the first report of 1996 (State of the Environment Committee 1996, 2001, 2006, 2011). All assessments have expressed an overriding concern that development along the coast has proceeded in a piecemeal and uncoordinated way, that cumulative impacts arising from discrete, additive and often interacting forces have often gone unquantified, and that the coastal environments are often degraded before they have been fully assessed and management and conservation objectives and priorities determined (State of the Environment Committee 2011).

The issue then becomes 'How can Australia's estuaries be repaired and will the benefits that accrue from repair be worth the investment?' We tackle this question by erecting a business case building on an inventory of readily achievable repair opportunities that was developed with all Australian states and the Northern Territory (Creighton 2013*a*, 2013*b*). To determine the break-even point for the proposed Australia-wide investment, three commercial fisheries were selected for analysis of likely improvements in productivity. Of these commercial fisheries, one was regional (Lower Lakes–Coorong–Murray Mouth, South Australia), one at the State level (estuarine floodplains in New South Wales), and one as a component of an iconic region (Great Barrier Reef, Queensland). The Australia-wide proposals for estuary repair outlined in the present paper are similar to activities already underway in the USA, as summarised below.

Coastal water bodies in Australia: what ecosystems are we analysing?

The Audit's 'modified' and 'extensively modified' coastal water bodies that we focus on in this paper are mostly those with the larger catchments, namely, the extensive coastal floodplains and the sheltered embayments around which there has been substantial development since European colonisation of Australia. Notable examples are the floodplain estuaries in Queensland south of Port Douglas, such as the Barron, Tully–Murray, Herbert, Burdekin and Delta, Fitzroy Rivers and their estuaries, through to Moreton Bay in the south-east of the State; in New South Wales, the Tweed, Richmond, Clarence, Macleay, Manning and Hunter River estuaries; in Victoria, the Gippsland Lakes, Port Phillip Bay and Western Port; in Tasmania, the Derwent and Tamar River estuaries; in South Australia, Spencer Gulf and Gulf St Vincent; and in Western Australia, the Peel–Harvey, Swan River and coastal waterways of the south-west of the State.

These are often the larger coastal water bodies and, by virtue of the size of their sheltered embayment waters, in-flowing rivers and the resultant magnitude of freshwater inputs, and associated wetlands, these are Australia's most ecologically productive coastal water bodies. They are also overwhelmingly the areas around which the Australian population lives, works and undertakes much of its recreation.

Estuarine degradation and falling productivity of fisheries: some Australian examples

Over 75% of commercial fish catch in Australia, and in some regions up to 90% of all recreational angling catch, spend part of their life cycle within estuaries and inshore wetlands (Copeland and Pollard 1996; Lloyd 1996; Bryars *et al.* 2003; New South Wales Department of Primary Industries 2007, 2008; Jerry 2013). Total populations of many inshore-fishery species have declined (e.g. Creighton 1982), and should habitat continue to be lost, it is almost inevitable that fish populations will continue to decline. Major fish kills in estuaries, often associated with the drainage of floodplain wetlands, the activation of acid-sulfate soils and alterations to freshwater flows, have been frequent events in New South Wales; examples of these include Clarence and Richmond River systems in 2009, 2010, 2011 and 2013 (Ryder and Mika 2013; see also White *et al.* 1997; Wilson *et al.* 1999; Johnston *et al.* 2003*a*).

For the 2013 event on the Clarence as an example, important recreational and commercial species killed included dusky flathead, *Platycephalus fuscus*, yellowfin bream, *Acanthopagrus australis*, garfish, *Arrhamphus sclerolepis*, luderick, *Girella tricuspidata*, and sea mullet, *Mugil cephalus*. Sampling just after the event could not detect live benthos from just below the tidal limit through to the ocean entrance (Ryder and Mika 2013).

Fisheries have been lost or degraded through a myriad of small decisions that have had an adverse effect on ecological condition and because associated works, such as drainage and the construction of roadways, causeways, training walls, floodgates and levees, did not fully consider the more public wetland assets or their likely effect on fishery production (e.g. Pollard and Hannon 1994; Kroon and Ansell 2006; Boys *et al.* 2012). Floodplain areas have often been developed for a single objective – additional lands for agriculture, for urban developments, or for industrial development. In many cases, the net result has been a suboptimal land-use pattern. Many areas drained and leveed with the objective of increasing agricultural production are at best marginal in their productivity and often have not been profitable as agricultural enterprises. In many cases, this marginally economic or uneconomic development for terrestrial agriculture has been undertaken at the expense of the pre-existing highly productive fishery industries that formerly took place in the adjoining waters. In hindsight, many works such as levees, floodgates, culverts, causeways and drains were less than optimally designed and often poorly located. However, through strategic reconfiguration, it is possible to repair critical parts of the coastal landscape, often re-establishing some fishery productivity, optimising floodplain agriculture profitability and improving amenity values such as flood control. (e.g. Environment Protection Authority 2003; Johnston *et al.* 2003*b*; Aburto-Oropeza *et al.* 2008; Government of South Australia 2009, 2012; Boys *et al.* 2012).

Case study 1 – Sydney rock oyster, New South Wales

The fishery based on the Sydney rock oyster, *Saccostrea commercialis*, in New South Wales is an excellent illustrative example of the effects of chronic degradation of coastal ecosystems. This is because the animals are cultured in a fixed location in the lower parts of estuaries and the health of the fishery integrates effects from the entire estuary and catchment. Additionally, as oysters are cultured, aspects such as catch effort and climatic influences are arguably not as variable as those for wild-caught fisheries. Likewise, the change in production cannot be attributed to changed management arrangements. To facilitate orderly development and management, there has been a consistent and competent set of licence and regulatory arrangements allocating areas available for lease since the late 1960s to early 1970s under New South Wales Fisheries.

Fig. 1 displays the annual production of Sydney rock oysters in New South Wales between 1950 and 2010. Improved cultivation techniques increased production until the 1970s, but a suite of degradative processes, including changes in catchment

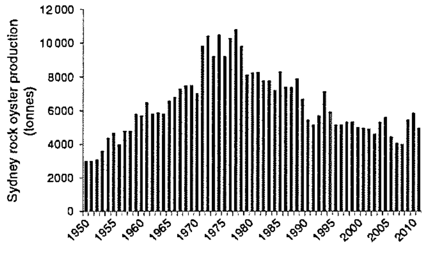

Fig. 1. Production from the Sydney Rock Oyster Fishery between 1950 and 2010 (Kirkendale *et al.*, in press).

land use, the loss of coastal wetlands, and more general estuarine water-quality degradation, have seen production decline markedly since then. In all major floodplain estuaries, the industry has been decimated by QX disease, caused by the protozoan parasite *Marteilia sydneyi*. The industry and indeed major populations of wild oysters no longer exist in these estuaries. These are also the estuaries that suffer from excessive wetland drainage and acid sulfate-derived poor water quality following flood events.

The decline in Sydney rock oyster yield has occurred despite ongoing improvements in growing technology, enhanced genetic stock, and increased consumer demand and price. Because of habitat loss and deleterious water quality, as well as abandoning oyster leases in major floodplain estuaries, the industry has replaced Sydney rock oyster with the more resilient Pacific oyster (*Crassostrea gigas*). In turn, the Pacific oysters that came to replace Sydney rock oysters have been affected by the virally mediated Pacific oyster mortality syndrome. There have been major kills of the more resilient Pacific oysters during the 2012 and 2013 floods with their accompanying poor water quality (Paul-Pont *et al.* 2013; see also www.oysterhealthsydney.org, accessed 28 January 2014).

Case Study 2 – prawn and scale-fish fisheries, New South Wales

The school prawn, *Metapenaeus macleayi*, is an annual, highly fecund stock that, if habitat is present, provides a resilient and highly productive commercial and recreational fishery. Yet in estuaries such as the Shoalhaven River, both the commercial and recreational fisheries have been lost since the early 1980s because of deteriorating estuarine condition. Similar comments apply to the western school prawn, *Metapenaeus dalli*, and the reduced productivity in the estuaries of south-western Western Australia (Potter *et al.* 1986, 1989; Smith *et al.* 2007).

In New South Wales, school prawn and eastern king prawn, *Penaeus plebejus*, fisheries are respectively considered fully exploited and overfished (New South Wales Industry and Investment 2010; Rowling *et al.* 2010). Catch rates are now ~75% of those that were maintained historically during the 1970s and 1980s, and some rivers now support only recreational prawn catches (New South Wales Industry and Investment 2010). Accordingly, eastern king prawn trawling fleets have reduced markedly, down from ~75 boats on the Clarence River

in the 1970s to fewer than 15 vessels. Similarly, the Estuarine General Fishery in New South Wales has never surpassed the levels of production of the 1960s and 1970s. For commercially valuable fisheries such as dusky flathead, *Platcephalus fuscus*, sea mullet, *Mugil cephalus*, sand whiting, *Sillaginodes punctatus*, *Sillago ciliate*, luderick, *Girella tricuspidata*, mulloway, *Argyrosomus japonicus*, and yellowfin bream, *Acanthopagrus australis*, average catches have declined markedly from those that were maintained in the 1960s and 1970s (New South Wales Industry and Investment 2010).

Part of the decline in these fisheries could be due to improvements in the rigour of fisheries management to ensure sustainability, as well as resource sharing as the recreational sector has increased in effort. Part could be due also to profitability issues, such as increasing input costs of diesel and labour or price competition from imported products. Nevertheless, the broad and consistent trends for most species in wild fisheries along the New South Wales coast indicate that the underlying factors of water quality and habitat loss predominate (Craig Copeland, NSW Fisheries, pers. comm.). Specifically, the reductions in total populations are likely to be due first to limitations to recruitment, growth and productivity due to loss of habitat and changes in tidal and freshwater flow regimes. Second massive water quality-induced kills are likely to have had an effect on total biomass, the almost total loss of some species (e.g. Sydney rock oysters and mud oysters, *Ostrea angasi*, from many NSW floodplain estuaries) and possibly overall species composition of estuary fish populations. Much of the water-quality decline, especially in changed pH, pollutants such as heavy metals, and anoxic or low dissolved-oxygen conditions is due to the draining of the critical estuarine habitats, the floodplain wetlands, salt marshes and accompanying seagrass-lined channels (Grabowski and Peterson 2007; Wood 2007; Government of South Australia 2009, 2012).

For wetlands on coastal floodplains, the activation of acid-sulfate soils is a critical water-quality problem and one that, across Australia, has often had a serious effect on fisheries and estuarine condition. The large floodplain rivers of northern New South Wales are especially subject to the activation of acid-sulfate soils, usually as a consequence of ill-advised drainage or alterations to wetland water regimes (White *et al.* 1997; Wilson *et al.* 1999; Johnston *et al.* 2003*a*). Acid-sulfate soils are soils that produce sulfuric acid (H_2SO_4) when exposed to the air. The essential component is pyrite (FeS_2), a highly insoluble crystalline form of iron sulfide that had been generated (usually within the past 10 000 years, during Holocene high sea levels) by the reaction of ferrous sulfide (FeS) with sulfur (Cook *et al.* 2000). On activation, the liberated sulfuric acid moves through the soil, stripping iron, aluminium and manganese, as well as dissolving, in the worst cases, heavy metals such as cadmium (Boon 2006). This noxious mixture makes the soil highly toxic and, combined with the very low pH (sometimes <3), renders plant growth impossible. Sufficient sulfuric acid can be produced that it seeps into adjacent waterways, resulting in drastic reductions in pH, massive fish kills, and the death of estuarine invertebrates, including economically important species such as shellfish. Even without fish kills, necrotic diseases such as epizootic ulcerative syndrome or red spot can make fish unsaleable and therefore grossly affect the value of fisheries.

Further research on these issues of fisheries productivity decline is certainly warranted. For example, NSW Fisheries Reports such as that by Kennelly and McVea (2001) have documented the re-entry of commercial species to the Richmond River in northern New South Wales after fish kills and following the return of improved water quality. Re-entry of target species after a freshwater input is a commonly observed phenomenon by both commercial and recreational fishers. However, after a fish kill it is not reincarnation; the stock re-entering an estuary will presumably be at most the total prior stock less the proportion of the stock that was killed in the event. Generally, it is the younger less mobile age classes and the sessile biota that suffer most from adverse water quality. There are also issues of interruption to growth rates that have not been adequately researched. Nevertheless, we suggest these research tasks should be of secondary priority to research linked to repair works. Linking research to repair works will ensure that any ongoing investment in repair of productivity can be increasingly more cost effective and efficient.

Case study 3 – black bream and the Gippsland Lakes, Victoria

The Gippsland Lakes system consists of three large coastal lagoons (Lake Wellington, 148 km^2; Lake Victoria, 75 km^2; and Lake King, 98 km^2), fed by seven rivers, plus an extensive mosaic of fringing wetlands. The lagoons have a shoreline of 320 km and the rivers drain a catchment of 20 600 km^2, just over 1/10 of the State of Victoria (Bird 1978). They support Victoria's largest commercial fishing fleet and the single largest recreational fishery for black bream, *Acanthopagrus butcheri*. The value of the commercial fish catch in 2005–2006 was AU \$1 224 000, made up mostly of black bream and dusky flathead, as well as the far less valuable but much more abundant carp, *Cyprinus carpio* (Department of Primary Industries 2007). The recreational catch is estimated to be worth at least as much as the value of commercial fishing, and includes black bream, estuary perch, *Macquaria colonorum*, snapper, *Pagrus auratus*, flathead and various species of squid, whiting and prawns. The social value of the Lakes for recreation, visual amenity, and in providing habitat for wildlife and biodiversity is reflected in the economic value of tourism. It has been estimated that in 2006, the Lakes attracted a total of 4 577 737 visitor days, including 2 326 247 spent in overnight visits and 1 436 000 in local day visits (URS 2008).

Despite these economic and social values, the ecological condition of the Gippsland Lakes has declined. Water quality now meets State-endorsed (State Environment Protection Policy) water-quality objectives only in dry years, when there is little runoff from agricultural lands (Environment Protection Authority Victoria 2010, 2013). The combination of altered salinity regimes and eutrophication has resulted in chronic blooms of the salt-tolerant blue-green alga, *Nodularia spumigena* (Cook and Holland 2012), and salinity conditions in the Gippsland Lakes are well suited for akinete germination and cellular growth (Myers *et al.* 2010; Holland *et al.* 2012). Chlorophyll *a* concentrations in the water column of Lake Wellington over the period 1990–2011 have exceeded 50 $\mu g\ L^{-1}$ and were frequently $>25\ \mu g\ L^{-1}$; concentrations in Lake King have sometimes exceeded 100 $\mu g\ L^{-1}$ (Environment Protection Authority Victoria 2013).

Table 1. Trend in commercial fisheries production in the Gippsland Lakes
Source: Department of Primary Industries (2007)

Species	Production per year (t)					
	1980–1981	1981–1982	1982–1983	2003–2004	2004–2005	2005–2006
Black bream *Acanthopagrus butcheri*	231	255	278	33	31	37
River garfish *Hyporhamphus regularis ardelio*	7	51	21	0	8	
Estuary perch *Macquaria colonorum*	0	0	0	1	1	1
Australian anchovy *Engraulis australis*	53	4	9	6	6	
Dusky flathead *Platycephalus fuscus*	23	26	30	11	12	47
Tailor *Pomatomus saltatrix*	51	45	19	59	39	14
Carp *Cyprinus carpio*	175	367	189	424	439	251
Yelloweye mullet *Aldrichetta fosteri*	81	106	77	49	36	22

Marked changes in fish populations have taken place, and few of the valuable freshwater taxa reported in the oral histories of early fishing families are now caught. Table 1 shows the decline in commercial fish catches (not corrected for unit effort) in the Gippsland Lakes over a recent two-decade period. Catches of black bream have dropped by nearly an order of magnitude and, in 2005–2006, were only 37 t. The decline in catches of black bream has continued since these data were collected, and is as low as it has ever been (Department of Primary Industries, see http://www.depi.vic.gov.au/, accessed 22 October 2014). The catch of Australian anchovy, *Engraulis australis*, is now trivial (<10 t). Carp now accounts for vast majority by weight (251–424 t) of the commercial fish catch. Part of the decline in black bream may be because this species can spawn only in a reduced array of areas with appropriate salinity regimes within the Lakes (Williams *et al.* 2012, 2013). There is also some evidence that the concentration of contaminants, especially mercury, in fish tissues is increasing (Fabris *et al.* 1999). Blair (2009) summarised the collapse of the black bream fishery and reported the perception of anglers targeting black bream in terms of the process of shifting baselines, whereby the present-day experience of the fishery is construed to be the 'natural' state and prior degradation is discounted (Pauly 1995; McClenachan 2009). Fish kills are now common in the Lakes: over the period 1998–2007, seven 'fish-death events' were recorded for the Gippsland Lakes area, the second highest in the State, after only Port Phillip Bay and Corio Bay (Environment Protection Authority Victoria 2007).

The benefits of estuarine repair

Overseas experience

Experience from overseas studies has clearly demonstrated that the repair of estuarine habitats yields considerable long-term benefits in terms of fisheries production, employment, and general quality of life. The European Union Water Framework Directive for Coastal and Transitional Waters has led to the development of multiple assessment and monitoring protocols, enhanced management and, in some countries, repair (e.g. Borja *et al.* 2010; Hering *et al.* 2013).

The USA experience in repairing fish, bivalve and crustacean productivity is perhaps the best reported from a fishery productivity perspective (e.g. Restore America's Estuaries 2012, 2013; Schrack et al. 2012), and has shown that rehabilitating estuarine environments leads to measurable increases in fish populations, which have positive effects on the communities and industries that depend on sustainable fisheries. Rebounds in fish populations can occur within months of rehabilitation works; in San Francisco Bay, rehabilitated salt marshes have improved populations of 41 fish species, including steelhead trout, *Oncorhynchus mykiss*, Pacific herring, *Clupea pallasii*, green sturgeon, *Acipenser medirostris*, and chinook salmon, *Oncorhynchus tshawytscha*. Since 2000, in Massachusetts and New York, Pacific herring, shad, *Alosa sapidissima*, and sturgeon populations have at least doubled following the rehabilitation of estuarine habitats; for example, within 2 years of a single culvert being repaired connecting Bride Brook to Long Island Sound, the Pacific herring population increased from ~75 000 individuals to ~287 000. In Chesapeake Bay, where reef structures were built covering ~35 ha, eastern oysters, *Crassostrea virginica*, quickly repopulated the new reefs, resulting in a 57-fold increase in the population, to ~185 million oysters within 5 years.

The social dimension of estuary repair

There are few studies of Australian estuaries that are comparable to those in the USA, but some information on productivity increases and most importantly the institutional setting, opportunities and constraints to habitat repair can be gleaned from repair works already undertaken. As part of developing the Australia-wide business case, pilot studies, supported by AU$200 000 of funding under the Commonwealth Biodiversity Fund, were undertaken to assess the institutional setting and likely impediments to estuary repair. These are detailed in a series of technical reports (Clarence Valley Council 2013; Moore 2013; Reef Catchments 2013; Richmond River County Council 2013). These pilot studies indicated that repopulation of degraded estuaries by at least some pioneer species of fish (e.g. barramundi, *Lates calcarifer*, and some species of mullet) in tropical estuaries can be rapid. Initial effects of reinstating estuarine conditions on important freshwater weeds (e.g. olive hymenachne, *Hymenachne amplexicaulis*, and para grass, *Urochloa mutica*) was quite rapid in the Burdekin study, but subsequent recolonisation by typically estuarine plant assemblages was not as rapid as for the pioneer fish species. Longer periods of monitoring than that able to be achieved in these 1-year project assessments are required. The studies were too short (1 year) to fully quantify the time taken until community assemblages and populations would improve fully.

In terms of social licence and the likelihood that the community would embrace repair of habitat, these studies provided some clear lessons (Creighton 2013*b*). Repair works within wholly public lands, such as national parks or other types of protected areas, are comparatively easy to undertake from administrative and from social-licence perspectives. In these cases, the land or water manager is often committed to repair, approval processes are streamlined, and community engagement is often more about promoting the success of the repair works than about seeking endorsement. In contrast, what might appear to be the simplest of repair works on public lands that are adjacent to freehold land uses can prove to be difficult to rectify in the short-term. In this particular pilot on the Clarence estuary, these difficulties occurred even though the structures are illegal and there has been no clear benefit of the prior works that degraded the estuary. The difficulty in rapidly gaining approvals to undertake repair works across the myriad of consent authorities is compounded if the local lead authority is risk-averse or has been captured by various lobby groups. In these cases, recreational and professional fishing and conservation groups would need to take a lead role in advocacy to counter the overall inertia of community resistance to change, if there is to be a social licence for repair works.

The pilot studies also demonstrated that repair works in agriculture-dominated landscapes are difficult and at best will involve substantial compromises. Where major rethinking of floodplain management is necessary to foster multiple benefits, including the return of fishery habitat and productivity, the time taken for community engagement and to develop a social licence will be considerable. Local leaders who are both visionary and advocates for change are essential for success. Examples of the roles of local leaders in other contexts include Smith (2007), Roberts (2008) and Carmin *et al.* (2012).

In contrast, estuarine repair within urban settings and where the lands and waters are earmarked for public open space and recreation are comparatively easy to implement from a community-engagement perspective. In these cases, the local community is often an immediate beneficiary of repair works, for example by the repair of fishery habitat, strongly supported by recreational and angling groups.

Fisheries productivity and estuarine repair

There are many examples in the literature of rapid recovery to fish assemblages following estuarine repair and, in particular, following improved connectivity. For example Boys *et al.* (2012) showed rapid fish responses following floodgate opening in the Mackay and Clarence Rivers, but did not document full system recovery and productivity as the wetland drainage systems were not repaired. New South Wales Department of Primary Industries (2011) provided a series of case studies on estuary responses to improved tidal flushing. For other estuaries, partial responses have proved to be less than optimum. For example Kraal *et al.* (2013) noted the complexity of sediment–water interactions in the Peel Harvey, south-western Western Australia, and questioned whether the investment in the Dawesville Cut to increase tidal flushing was a worthwhile investment.

For very few Australian estuarine systems, a total repair initiative has been implemented and little has been documented as to changes in fishery productivity. The best example of a total repair initiative is probably Wallis Lakes. It demonstrated that measureable outcomes can be achieved with a focussed and thorough investment in whole-of-system improvement. Wallis Lakes was closed as an oyster fishery after a hepatitis scare and poor water quality, especially emanating from septic tank leachate. The Great Lakes Council acted to remedy septic-tank leachate and has been using levy arrangements to buy and rehabilitate affected wetlands, especially those with extensive acid-sulfate soils. Wallis Lake is now among the cleanest oyster farming areas in New South Wales, with harvest now permitted throughout the year, including during major rain events and substantial runoff conditions (Great Lakes Council 2012).

Opportunities for estuarine repair – what needs to be done

Five discrete repair themes can be identified. The first is to restore longitudinal and lateral connectivity to ensure fish passage and nutrient flux (Sheaves *et al.* 2014*a*). This will involve removal of barrages, inadequate culverts and causeways and other blockages to the movement of animals and plants, their propagules, tidal and freshwater flows, and the flux of nutrients. The second is rehabilitating degraded floodplain wetlands, which can be achieved in part by removing or manipulating barrages to allow more natural fluxes of water, and reshaping landforms to remove drains and levees. Acid-sulfate soil will require particular attention (Cook *et al.* 2000). The third is re-establishing mussel and oyster reefs, which provide valuable habitat and nursery areas for many estuarine fish species, as well as performing valuable water-quality improvement functions. The fourth is protection and, if required, re-establishment, of seagrass beds. The provision of seagrass-friendly moorings in areas subject to heavy recreational boating is likely to be an important component of this action. Finally, the defining characteristic of estuaries – that they are the meeting place of fresh waters and marine waters – needs to be acknowledged by maintaining both adequate freshwater flows to the lower reaches of coastal floodplain rivers (Gillanders and Kingsford 2002) and tidal flows from the ocean.

Re-instating connectivity for biological, chemical and hydrological fluxes is key to re-establishing estuary fisheries productivity. Barriers to connectivity occur along almost every river and estuary in the more populated parts of Australia. For example, studies in the Great Barrier Reef catchments have identified in the North Queensland Dry Tropics region from Rollingstone to Bowen over 12 000 barriers to fish passage (Carter *et al.* 2007). In New South Wales, there are over 4000 weirs and other major structures that limit fish movement on rivers and streams, of which at least 1700 occur on coastal waterways (New South Wales Department of Primary Industries 2006). This maze of barriers was constructed in times past when knowledge about fish movements was lacking and when the single motive for river regulation was agricultural development on floodplains. Constrictions on tidal flows by various engineering works such as bridges, causeways and floodgates affect both physical and biotic flows and fluxes. Tidal flow, the interactions with fresh water and the mixing zone of brackish water are what ensure that estuaries are among the most productive – and valuable – of the world's ecosystems.

Table 2. Outline of expenditure required to rehabilitate Australian estuaries to achieve measurable increases in fisheries production

Activity	Cost (AU$)	%
Planning: all aspects to ensure approvals, undertake surveys such as tidal penetration, document proposals and likely return on investment of each proposed project.	$21 million	6
Works: generally under some form of tender or contract arrangements with the owner: including fish passage, estuary and wetland repair and complementary works to ensure smarter floodplain and estuarine ecosystem management.	$238 million	68
Monitoring: based on sound science, covering habitat importance, repair and fisheries re-establishment priorities and habitat–population protocols to estimate likely improvements in productivity and selected monitoring to ground-truth these protocols. Will need to recognise climate variability and its influence on populations.	$24.5 million	7
Reporting progress: summarising the outputs and longer-term likely benefits or outcomes of the total investment, undertaken annually and including an evaluation of progress and assessment of estuary condition in Year 4.	$10.5 million	3
Program communication, legacy arrangements and marketing: building on existing communication activities, marketing to the broader community the value of proactive repair and management of estuarine and nearshore ecosystems, linking to the Australia-wide Habitat Network and designing and fostering the implementation of community-led legacy arrangements. Also covers oversighting activities such as expert-based Australia-wide steering-committee and program-management activities.	$17.5 million	5
Policy development: fostering comparable policy and regulations in each state for estuarine and nearshore habitat protection, repair and for development offsets.	$17.5 million	5
Research: cost-effective repair and priority investments – building on existing knowledge of the estuarine dependence and preferred habitats of key species to predict priorities for all follow-on works and activities after this 5-year investment.	$21 million	6
Total	$350 million	100

Catchment management, improved point-source pollution control and changes to land use have meant that overall water quality has improved in many embayments such as Port Phillip or Moreton Bay. It may now be appropriate to re-establish essential components of within-estuary habitat, such as the oyster and mussel reefs that once characterised coastal sheltered embayments from Moreton Bay south to D'Entrecasteaux Channel (Beck *et al.* 2011). Such repair is similar to initiatives already underway in USA, where, as with Australia, point- and diffuse-source water pollution is much reduced and fishery management is already well in place (Newell 2004; Kemp *et al.* 2005; Kroeger 2012; Schrack et al. 2012).

Linked to connectivity and overall estuary-ecosystem performance is the quality of remaining wetland habitat. Changed hydrological and tidal flow patterns that have accompanied catchment development have severely degraded seagrasses, salt marshes, mangroves and coastal brackish-water wetlands (West *et al.* 1985; Jensen *et al.* 2000; Thomas and Connolly 2001; New South Wales Department of Primary Industries 2007, 2008; Mackenzie and Duke 2011; Sinclair and Boon 2012; Boon *et al.* 2014). Re-establishing tidal flows to wetlands in dry times, reconfiguring wetland drainage systems to more closely mimic their natural flood hydrology during flood events and infilling drains to reduce acid-sulfate potential will all enhance productivity of fisheries.

All the above actions will be less than optimum unless estuaries receive adequate freshwater and tidal flows. Gillanders and Kingsford (2002) reviewed available information on the effect of freshwater discharge on estuarine fish in Australia, noting a commonly observed reduction in commercial fisheries after reductions in freshwater flows to estuaries. More recently, Scheltinga *et al.* (2006) reviewed the literature available on the effect of freshwater flows on commercial fish catches. Only few Australian fish species have been studied so far, but it is known that catches of sea mullet, barramundi, luderick, school, tiger, eastern king and banana prawns and dusky flathead all showed positive relationships with freshwater flows; in contrast, catches of yellowfin bream and whiting species sometimes did not. Analyses of recreational angling data suggest a positive relationship between fish catch and river discharge in the Burdekin and Fitzroy Rivers of central Queensland, as do commercial data for commercial fisheries of the Capricorn–Bunker Group of the Great Barrier Reef. In the latter case, the positive relationship held for fish as diverse as coral trout, *Plectropomus* spp., cod, *Epinehelus* spp., pearl perch, *Glaucosoma scapulare*, hussar, *Lutjanus adeti*, king threadfin, *Polydactylus macrochir*, and snapper.

A business case for estuarine repair

The business case for the repair of Australia's estuaries was built through two parallel processes. Expert opinion from all States and the Northern Territory identified and costed a suite of 'Tier 1' high-priority repair opportunities (Creighton 2013*b*). 'Tier 1' repair opportunities were those that were assessed to be of likely substantial benefit to fisheries productivity, to be achievable from a biophysical perspective and most importantly to be acceptable from a social-licence perspective. These proposed works totalled AU$238 million.

To comprise the total suggested investment of AU$350 million, additional allocations were proposed for aspects such as planning, communication, monitoring, policy development and reporting (Table 2). All these aspects are essential if the social, economic and environmental benefits of repair following such a major investment are to be accurately measured, communicated widely and hopefully lead to multiple follow-on activities in fisheries habitat repair and protection. The proposed estimates for expenditure on these aspects were all based on the percentage effort recommended by the Australian National Audit Office for major environmental programs (ANAO 2013).

Table 3. Projected increased value of commercial species for economic assessment 1, the Lower Lakes–Coorong–Murray Mouth fishery

Target species	Historical catch (t)	2011–2012 catch (t)	Increased productivity (%)	Value 2013 (AU$)	Projected value 2018 (AU$, using 2013 AU$ values)
Mulloway	14–106	64	20	$438 000	$526 000
Comments: mulloway, *Argyrosomus japonicas*, spends much of its post-larval and juvenile phases in sheltered environments such as the Murray–Coorong estuary, proceeding to sea to spawn. Being a piscavore, mulloway productivity is an excellent indicator of overall system health. Adult mulloway at Age 3+ is caught nearshore.					
Yelloweye mullet	110–346	144	20	$585 000	$702 000
Comments: yelloweye mullet, *Aldrichetta fosteri*, is found in brackish and inshore coastal estuaries and has a preference for shallow estuaries.					
Black bream	1–47	3	20	$37 000	$44 000
Comments: black bream, *Acanthopagrus butcheri*, completes its entire life cycle within an estuary and tolerates a range of salinities from fresh to hypersaline. There appears to be a high degree of estuary fidelity. Bream is vulnerable to poor water quality.					
Greenback flounder	0–65	31	20	$249 000	$298 000
Comments: adult greenback flounder, *Rhombosolea tapirina*, prefers sand silt and muddy substrates in bays, estuaries and inshore coastal waters. Adults sexually partition habitat, with females being more abundant in shallow water and males more abundant in deeper water. Post-settlement and juvenile flounder tend to be found in shallower water and prefer unvegetated sand and mudflat habitat where they are well camouflaged. Juveniles tolerate a wide range of changes in salinity and are often found in the upper reaches of estuaries and occasionally in rivers.					
Total estimated productivity value increase for these selected species post-2018: at least AU$0.0.26 million per annum. Break-even point for proposed Coorong–Murray Mouth investment: <7 years					

In parallel, three case studies were undertaken to test the likely return period for break-even on the proposed Australia-wide investment. The case studies were selected to broadly cover the scale and nature of proposed repair activities.

Australian Government leadership was proposed because leadership from the Australian Government brings with it multiple benefits; such involvement facilitates the 'big picture' vision that is necessary for investments that will deliver equally big outcomes; it fosters an integrated and priority investment approach; it brings with it increased opportunities for co-investment from both the private sector and from state and local governments; it is more likely to benefit total fish stocks with flow-on in increased productivity from repair in one estuary being realised in catch in another region or state; and most importantly Australian Government leadership fosters a series of discussions about how to improve public policy so that ongoing investment is at a much reduced level and focussed on sustaining the improved condition of our public estuary assets with their multiple benefits to the Australian community. Most of any ongoing investment can be achieved through smart state-level policies, and through existing revenue-collection activities such as boat and fishing licences that are then reapplied to fishing benefits and community action.

Case study 1 – a single estuary: the Coorong, South Australia

The Lower Lakes–Coorong-Murray Mouth has in place already a Marine Stewardship Council certified fishery in terms of fishing methods and allowable catch. Species used in this analysis are juvenile and adult mulloway, black bream, greenback flounder, *Rhombosolea tapirina*, and yelloweye mullet, *Aldrichetta fosteri*, in part because they are commercially important, but also because their life histories and estuarine dependence are well documented. During dry phases, porpoises and their prey such as Australian herring, *Arripis geogianus*, and yelloweye mullet once travelled at least as far upstream as the Murray River proper above Wellington. Up until the construction of the causeway and barrages, there were over 100 mulloway fishers based on the northern Coorong, providing Adelaide with most of its seafood needs. Even with its ecological function grossly impaired because of the loss of interconnectedness between freshwater and estuarine ecosystems, the Lower Lakes–Coorong–Murray Mouth complex is of such high conservation value that it is on the World Heritage Register. Repair works to increase connectivity between the Coorong and Lower Lakes will markedly improve its ecological values.

The now much reduced commercial fishery, has a current annual economic value of AU$5.7 million per year. As shown in Table 3, estimated fishery productivity improvements of 20% across all key species could lead to comparable increases in the annual economic value. These estimated values are based on South Australian market prices and are therefore conservative. For species that are sold interstate such as mulloway and pipi, the price received is often higher. Although the fishery is comparatively small, the economic and employment benefits to the regional community are substantial. Equally important, but unable to be valued at this time, are the benefits of a productive Murray estuarine fishery to coastal waters and estuaries of the lower south-east in South Australia and all the southern estuaries of Victoria. It is likely that the Murray estuary is a critical source for recruitment to the inshore and estuarine environments to the east.

Pipis or cockles, *Donax deltoids*, are an integrator across the fishery in that with diatoms dominating their feed, a healthy and productive estuary linked to a healthy and productive freshwater system will foster a productive cockle resource. Congoli, *Pseudaphritis urvilli*, is an example of a major contributor to the food web and therefore feed stocks for higher-order piscavores such as mulloway. Congoli has a lifecycle that includes fresh-water and marine or estuarine phases. Re-establishing connection through all the small creeks that once dominated the islands will foster a rapid increase in overall Congoli

Table 4. Non-costed and non-market benefits in the Lower Lakes–Coorong–Murray Mouth economic assessment

Non-costed and non-market benefits	
Recreational fishing	Mulloway, black bream and, to a lesser degree, greenback flounder are all target species. With estimates of productivity increases of ~20%, the stock available for recreational catch will also increase. Equally important are the likely flow-on benefits of increased fish populations across south-eastern South Australia and the many estuaties and related nearshore areas of the southern Victorian coast.
Coastal biodiversity	The Coorong is already recognised as a World Heritage Area. By increasing the area of brackish to saline mixing zone in the Coorong and commensurately reducing the excessive saline levels in the southern Coorong, these World Heritage values will be benefited right across the food chain from benthic flora and fauna through to the many species of waterfowl and migratory waders that frequent the Coorong.
Carbon sequestration	By increasing the productivity of the mid- to southern Coorong, seagrass extent and vigour will markedly increase.
Tourism	The Coorong region attracts large numbers of tourists who undertake water sports, bird watching and general leisure. Increasing estuary productivity will increase tourism, particularly associated with recreational fishing, bird watching and boating.
Indigenous and cultural values	The Ngarrindjeri have strong traditional ties to the land and sea. The ability to harvest from the Coorong is a cultural value of the Indigenous custodians that will be enhanced by returning the Coorong to historical productivity levels. Many of species are totems for the Ngarthii culture and have cultural value.

population to the benefit of the entire food chain. Table 4 lists the main non-costed and non-market values that will accompany investment into repair of the Coorong estuarine system.

Case study 2 – estuarine floodplains in New South Wales

Most of the popular species for catch or eating, such as school prawn, eastern king prawn, Sydney rock oyster, yellowfin bream, dusky flathead, sand whiting and various species of mullet, spend much or all of their life history within estuary–wetland systems such as the Cobaki, Tuckean, Wooloweyah, Everlasting, Big Swamp, Tomago and Hexham swamps.

Using the Clarence River estuary as an example, proposed repair works would include improved connectivity (e.g. removing unnecessary levees and ring drains at Lake Wooloweyah), enhanced tidal flows (e.g. dismantling parts of the entrance middle wall and increasing the number of road culverts for Shallow Channel) and a re-establishment of floodplain wetland functions (e.g. Broadwater and Everlasting Swamp wetlands).

Productivity improvements are projected for Sydney rock oyster, mullet and school prawn. The reduced productivity of the Sydney rock oyster across much of New South Wales has been previously discussed. Mullet species (*Mugil cephalus* and *Myus elongatus*) are caught from the estuary general and ocean haul fisheries during its spawning migrations along the coast. Mullet is deceptively considered a low-value family seafood, being, to some degree, underrated by the consumer marketplace. It provides the largest biomass of commercial catch in New South Wales and provides high-value export roe products, as well as business operations for Aboriginal Australians. Although a very sustainable species with high fecundity, in the past decade, the average catches have dropped by ~50% compared with prior long-term catches. Considering the high fecundity, it is unlikely that lack of reproductive output is a significant contributor to this reduction. The evidence for recent disease outbreaks of red spot lesions and reduced populations suggests that poor floodplain management is the major contributor to the decline. Mullet, being a herbivore low in the estuary food chain, is closely linked to the net primary productivity of the estuaries and the ecological health of fresh–brackish coastal wetlands. Repairing fresh–brackish wetlands is expected to lead to comparatively rapid increases in mullet populations.

School prawns are highly fecund annual stock with close correlations between stock and climate, with wetter years with more brackish estuaries and more connection between estuary and wetlands leading to higher populations. School prawn spawns close inshore, with almost immediate recruitment to estuaries and provides the fifth-highest biomass of commercial fish catches in New South Wales across three sectors, estuarine general, prawn trawl and ocean haul. During early growth phases, salt marshes and mangrove and brackish wetlands are preferred habitat. As the prawns mature they move to estuary muds and seagrass areas and, once ready to spawn, rise from the bottom during dark periods (no moon) and run against the tide to the ocean. Being highly fecund and an annual population, it is assumed that once water quality, access and habitat are repaired, the prawn population will rapidly respond. For example, prawns were found in open tributaries in seine net catches of up to 3–4 orders of magnitude greater than catches just below floodgated tributaries and their acid-sulfate leachate. Thus, the potential of a 3–4-fold increase in prawn productivity through floodplain repair is suggested and recognising the magnitude of the drained wetland and floodgate problem, this is probably an extremely conservative estimate.

The repair works advocated for New South Wales are estimated to at least double fishery productivity in the State (Table 5). Commensurate flow-on increases in both recreational and inshore professional fishing for other species are likely. Other important commercial species not valued in terms of productivity improvements but likely to benefit from estuary repair include eastern king prawn, yellowfin bream, dusky flathead, luderick, mulloway, garfish, eels and whiting. Other non-costed and non-market values of the repair of estuarine floodplains in New South Wales are detailed in Table 6.

Case study 3 – an iconic region: estuaries associated with the Great Barrier Reef

To complete the case studies, a thematic repair opportunity of re-establishing salt marshes by removing ponded pastures and thereby also re-establishing accompanying estuary tidal

Table 5. Projected increased value of commercial species for Economic assessment 2, New South Wales estuarine floodplains

Target species	Historical catch (t)	Current catch (t)	Increased productivity	Value 2013 (AU$)	Projected value 2018 (AU$, using 2013 AU$ values)
Sydney rock oyster, *Saccostrea commercialis*	140 000 bags Sydney rock oyster only	39 475 bags Sydney rock oysters 2720 bags Pacific oysters	Return to at least 1970 production levels	$30.3 million	$100.4 million
Comments: oysters are an integrator of overall estuary condition and most importantly the net primary productivity within that estuary. (Refer to case study for details of decline in production.) Data source: Creighton (2013*b*).					
Mullet, *Mugil cephalus*; and *Myxus elongatus*	<3000 t; 200 t	>5000 t; 120 t	Return to at least mid-1990s levels	$30 million	$50 million
Comments: mullet is closely linked to the net primary productivity of the estuaries and to fresh to brackish wetlands, being low in the estuary food chain. Repair of wetland function is expected to lead to comparatively rapid increases in its population.					
School prawn, *Metapenaeus macleayi*	>1000 t	674 t	Return to at least mid-1980s levels	$8 million	$12 million
Comments: because school prawn is highly fecund and an annual population, it is assumed that once water quality, access and habitat are repaired, the prawn population will rapidly respond. (Refer to case study for decline in NSW)					
Total estimated productivity-value increase for these selected species post-2018: at least $94 million per annum. Break-even point for proposed New South Wales estuarine floodplain investment: <3 years					

Table 6. Non-costed and non-market benefits in the New South Wales estuarine floodplains economic assessment

Non-costed and non-market benefits	
Recreational fishing	Yellowfin bream, dusky flathead, sand whiting, luderick, sea and river garfish, mulloway, mud crabs and, to a lesser degree, blue swimmer crabs and school prawns are all target species and will all benefit from estuary repair.
Reduced likelihood of anoxic events and acidic leachate causing fish productivity or biodiversity losses and diseases	The major thrust of much of the repair investment is to re-establish key wetland complexes, removing levees and floodgates that isolate the tide and fish from these major nursery areas and rehabilitating drains within these complexes. The repair of these major assets will remove much of the cause of the low dissolved oxygen, acidic black water that characteristically is dumped from these grossly disturbed ecosystems. Major fish kills are expected to be reduced in frequency and severity, with flow-on benefits to overall estuary biota. Similarly, these extreme event discharges are implicated in major oyster kills and diseases.
Coastal biodiversity	These wetland complexes with their fresh to brackish to sometimes almost seawater salinity are extremely productive in their natural condition for many species of waterfowl, including at least seven species of duck, several species of cranes, and other taxa such as cormorants, brolgas, darters, ibis, egrets and migratory waders.
Carbon sequestration	Many of the current poor-condition wetland complexes export methane from their peaty soils, contributing to the overall pollution budget of greenhouse gases. Re-establishing their ecological functions will change these systems from net exporters of greenhouse gases to net sequesters. Noting that the 1% of Australia that is coastal wetland sequesters ~39% of Australia's carbon; the benefits are substantial.
Improved flood control	1960s style flood-control systems and implemented as 'flood mitigation' have proven to be inadequate, often holding up flood heights in the lower part of the catchments. Multi-objective redesign of catchment flood-control and floodwater management will benefit urban populations, agriculture and fisheries.

channels and gutters and seagrass beds was selected. This was geographically restricted to the Great Barrier Reef estuaries to also demonstrate the benefits for an iconic region, the Great Barrier Reef World Heritage Area. Banana prawns, *Fenneropenaeus merguiensis*, and tiger prawns, *Penaeus esculentus* and *Penaeus semisulcatus*, were the species selected because these are annual populations likely to increase in biomass quickly once repair of habitat is effected, and species for which their life history dependence on salt-marsh or estuary channels is well documented (Sheaves *et al.* 2007*b*).

Banana prawns spend their larval, post-larval, juvenile and subadult phases in estuarine environments, especially mangroves and salt marshes (Vance *et al.* 1990; Sheaves *et al.* 2007*a*, 2012), with adults then exploiting coastal environments (Staples and Vance 1986). As with other crustacea, the limited science available on their early phases suggests that banana prawns are likely to be an excellent indicator of improvements in salt-marsh condition such as removal of bunds on ponded pastures and of increased tidal flows as accompany removal of all in-stream barriers. Tiger prawns spend their larval, post-larval and juvenile phases in lower estuarine environments, especially seagrasses (Loneragan *et al.* 1998). Increased productivity of tiger prawns follows from increased health and vigour of seagrass beds and thus from improved water quality/reduced turbidity (Waycott *et al.* 2005; Grech *et al.* 2011).

The research has yet to be undertaken to precisely quantify reductions in productivity of banana and tiger prawns with reduction in habitat availability or quality. Further, the historical data on catch are very incomplete, let alone any useful estimates of catch as a proportion of total available stock (Sheaves *et al.* 2014*b*). Many of the changes to habitat for both of these prawn species were well underway by the late 1950s and 1960s. Excessive turbidity and the loss of seagrasses accompanied grazing, agriculture and road development in the catchment (Grech *et al.* 2011). Drainage and loss of wetlands and connectivity, including the construction of bunds started in the same period. Ponded pasture construction was initiated in the early 1980s, probably came to a peak in the early 1990s and was discouraged from ~1995 onward because of the effects on prawn stocks and fisheries generally (Grech and Coles 2011; Sheaves *et al.* 2014*b*). To attribute precisely the cause of the decline in total prawn population from 1950s onward is impossible. There has also been a very confounding variety of changes to catch effort, improvements in the methods of catch and gear, including moving to more efficient nets, triple and now quad gear, better knowledge of where to concentrate effort and changes in entitlements and restrictions on effort accompanying changes in Great Barrier Reef zoning (Sheaves *et al.* 2014*b*). Although these factors make any estimates of reductions in prawn productivity difficult, the data on tonnage production available from 1990 to 2009 suggest a decline in total commercial catch from ~5500 t to ~4000 t over this period.

Even if the most repair we can achieve is in returning habitat available and improved connectivity to the level of those of ~1990, and assuming that 50% of the improvements are in the more valuable tiger prawn population, then the approximate increased value of commercial product would exceed AU\$45 million per annum at 2013 prices. No estimates can readily be made for the many other species that would benefit.

Other iconic Great Barrier Reef species that have a very clear estuary dependence include barramundi, *Lates calcarifer*, mangrove jack, *Lutjanus argentimaculatus*, and mud crab, *Scylla serrata*. Barramundi post-larvae and juvenile phases up to at least 3 years of age feed and grow within estuarine to fresh environments (Russell and Garrett 1985, 1988), with juveniles being dependent on access to brackish coastal wetlands (Davis *et al.* 2012, 2014). This close dependence on brackish wetlands means that the sizes of exploitable stocks of barramundi are tied to access to wetlands and wet-season flooding (Staunton-Smith *et al.* 2004; Sheaves *et al.* 2007*a*; Sheaves and Johnston 2008). However, large areas of these coastal wetlands have been lost, or connectivity to them has been destroyed, throughout the Great Barrier Reef region (Sheaves *et al.* 2007*b*, 2014*b*), so repair of these habitats provides a substantial opportunity for great enhancement of barramundi stocks. Increases in Barramundi productivity would be a broad indicator of connectivity and associated increased area of improved habitat. For example, the work now underway on the Fitzroy as part of Reef Rescue II will provide passage through wetlands to the upper Fitzroy around the main weir just above Rockhampton and will ensure barramundi has access to at least another 120 km of main river channel, without counting side channels, contributing rivers and creeks (Stuart and Mallen-Cooper 1999).

Have the benefits been overestimated?

The three case studies indicated that substantial returns will accrue from a modest investment into rehabilitating Australia's estuaries. The estimates of return and on 'break-even' points that we have used are all highly conservative. For several reasons, it is unlikely that the benefits have been overestimated. First, only a subset of commercial species was selected. Recognising the estuary dependence of many other species, their life-history similarities to the selected species, and the likely interactions between all species and an improved net primary productivity, other commercial catch species will also benefit. Second, to ensure a conservative estimate, all other fishing and non-market benefits were ignored; for example, no values or even estimates of recreational or indigenous fishing benefit were included in the break-even analysis. We leave it to others to speculate on estimated equivalent dollar values for what this analysis regarded as 'externalities', including the flow-on benefits to fishing-tackle shops, tourism, marine centres and so on. Likewise all the multiple non-market values of estuary repair that are generally termed 'ecosystem services', such as biodiversity, landscape amenity, lifestyle improvements, water quality, flood control, coastal buffering, carbon sequestration, buffering against climate-change impacts and so on, were not valued.

Third, it was assumed that demand for seafood product would be totally elastic – that is, domestic demand would expand to take up all the additional seafood productivity. Any economic benefits of Australian product replacing imported product was excluded from the analysis. At the very least, assuming no growth in the Australian population nor in the demand for seafood, it can be assumed that increase in Australian product available would probably partly replace imported seafood.

To continue with this approach that focussed on simplicity and under-estimating the likely benefits, market and economic conditions were assumed static as at 2013. That is, there were no increases in value factored in from such as consumer price index or for buyer preference for the fresher Australian product or indeed any other market-related changes in product dollar value.

Applying these conservative assumptions and considering only the value of the three selected commercial fisheries, an Australia-wide investment of AU\$350 million would be returned in less than 5 years, merely from the returned productivity for the species selected from these three commercial-fishery case studies.

If the case is so strong, why has the investment not been made earlier?

If the readily measurable returns are so positive with ongoing positive returns long into the future, why has there not been much more attention paid to rehabilitating degraded estuaries in the past? Certainly, Australia has had, and continues to enjoy, substantial investment in environmental works through initiatives such as Landcare, the Natural Heritage Trust, the National Action Plan for Salinity and Water Quality, Caring for

our Country, and the Biodiversity Fund. Many of the projects and activities funded under these investment streams would have difficulty in demonstrating any form of economic return, let alone the types of ongoing sustainable benefit of food production and related public benefits that can so easily be quantified for repairing estuary productivity. Indeed, Brooks and Lake (2007) reported that only 14% of government-funded river-restoration projects in Victoria had any form of monitoring; under such conditions, it is simply impossible to calculate the effectiveness of repair works and return of investment.

We posit that there are three reasons for the continuing decline in estuarine fisheries and, more broadly, in estuarine condition and why this decline has not been addressed by a suitable investment into estuarine repair. These include (1) neglect of investment opportunities by senior administrators for the coastal zone, in comparison with putatively more pressing issues facing inland regions (e.g. Boon 2012); (2) lack of an informed public regarding the functioning and value of coastal/estuarine systems (e.g. Zann and Dutton 2000; Ipsos-Eureka 2008; Boon *et al.* 2011); and (3) unforeseen, or at least ignored, effect of other private-benefit resource uses on coastal or public-benefit ecosystems (e.g. Harris *et al.* 1996; Jensen *et al.* 2000). These various components are interactive and not mutually exclusive.

It is hoped that the business case outlined in the present paper helps contribute to the debate as where to best invest in environmental repair in Australia. It is our contention that return on investment into estuarine repair would occur in far shorter timeframes than the more traditional investment in ecosystem repair such as in soil health, wildlife corridors, or terrestrial biodiversity repair and the dollar returns are likely to be far more immediate. Repairing degraded estuarine ecosystems, although challenging and often requiring a case-by-case approach, can demonstrably rapidly yield benefits to fisheries production with a wide range of flow-on outcomes to the Australian economy, job provision and lifestyle.

There is much that could be done if Australia were to invest in these public assets. As to why this very attractive investment opportunity has not yet been taken up in a strategic manner, perhaps the words of Aristotle in the 4th century BC remain as relevant today as then: 'That which is common to the greatest number has the least care bestowed upon it'.

Conclusions

The repair of degraded estuaries provides an exemplar demonstration of how focussed investment in an environmental setting can yield exceptional return to all aspects of the Australian economy. Tangible monetary benefits are readily quantifiable. There are also multiple other non-dollar value ecosystem services and community benefits accruing from estuarine repair.

Australia, an old nation from a geomorphological perspective, has developed its current land-use pattern in just over 200 years. Much has been learnt scientifically along the way as to the effects of our land- and water-allocation decisions and our land practices on the Australian environment, namely, changes to water quality and sediment load, the mobilisation of salts by dryland salinity, the loss of biodiversity and the reduction of fishery productivity. As typified by the AU\$1.4 billion National Action Plan for Salinity and Water Quality and the AU\$400 million Reef Rescue environmental programs, Australia has invested substantially in the task of improving agricultural-land management practice. We suggest it is now timely to add the concept of estuarine repair and land-use optimisation to the toolkit of environmental repair investments.

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Adapting management of marine environments to a changing climate – a checklist to guide reform and assess progress

[Short title - Climate adaptation checklist]

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ABSTRACT

Documented impacts of climate change on marine systems indicate widespread changes in many geographic regions and throughout all levels of the ocean's food webs. Oceans provide the main source of protein for over a billion people, and contribute significantly to food security for billions more. Clearly, the rate of adaptation in our human systems needs to at least keep pace with the rate of ecological change for these benefits to continue. An Australia-wide program of research into marine biodiversity and fisheries explored the opportunities for policy and management to respond to a changing climate. The research program spanned all Australian estuarine-nearshore and marine environments – tropical, subtropical and temperate – and focused on two key marine sectors: biodiversity conservation and fisheries (commercial, recreational and aquaculture). Key findings from across this strategic and extensive research investment were the need to foster resilience through habitat repair and protection, improve resource allocation strategies, fine-tune fisheries management systems and enhance whole of government approaches and policies. Building on these findings, from a climate adaptation perspective we generated a checklist of thirteen elements to assess and steer progress towards improving marine policy and management. These elements are grouped in three broad areas: preconditioning; future proofing; and transformational changes and opportunities. Arising from these elements is a suite of priority strategies that provide guidance for marine managers and stakeholders as they prepare for a future under climate change. As our research program encompassed a wide range of habitats and ecosystems, spanned a latitudinal range of over 30 degrees and considered a diversity of management systems and approaches, many of these elements and strategies will be applicable in a global context.

Keywords: marine biodiversity, fisheries management, marine conservation, climate change, adaptation, transformation

INTRODUCTION

Oceans policy and management has a broad dual remit, to foster both sustainable use and biodiversity conservation (UN 1982, Article 61). This dual remit is a global challenge, particularly given the increasing pressures on the ocean as a result of human activities and the demand for seafood from a growing population (Halpern and others 2012; Maury and others 2013; Ban and others 2014; Merrie and others 2014). Production of natural resources from the oceans already exceeds the capacities of natural systems in many areas (Miles 2009), and the functioning of major biogeochemical cycles and ecosystems have been altered by anthropogenic impacts (Doney and others 2012). Yet oceans provide irreplaceable ecosystem services including defence, oxygen production, nutrient recycling and climate regulation (Costanza and others 2014; Polovina and others 2014) valued globally in 2011 (2007 $US) at $125-$145 trillion/yr (Costanza and others 2014). Australia's surrounding oceans, representing the world's third largest EEZ (~8.1 million km^2), are no exception (SoE 2011). These oceans generate considerable economic wealth through fisheries, aquaculture, tourism, oil and natural gas, and transport, estimated as $A42 billion per year or about 8% of gross domestic product (AIMS 2012). Fisheries and aquaculture are important industries in Australia, both economically (gross value over $A2.5 billion) and socially (Madin and others 2012; ABARES 2013). In addition to significant intrinsic natural values, the annual economic value of Australian marine biomes in terms of delivery of ecosystem services have been estimated as: open ocean $A464.7 billion, seagrass/algal beds $A175.1 billion, coral reefs $A53.5 billion, shelf systems $A597.9 billion and tidal marsh/mangroves $A39.1 billion (Blackwell 2005).

As in other regions, Australia's oceans, marine biodiversity and dependent industries (e.g. fisheries and aquaculture) are already experiencing and responding to a changing and more variable climate (Lough and Hobday 2011; Poloczanska and others 2012; Hodgkinson and others 2014). The flow-on effects from climate through to ecological and economic change are occurring at a more rapid rate in marine compared to terrestrial systems (Poloczanska and others 2013). Adapting to this changing climate is essential if Australia is to maintain, build upon and profit from the wealth of public and private goods and services provided by the marine environment (Holbrook and Johnson 2014; Hodgkinson and others 2014; Johnson and Holbrook 2014). Moreover, there are 50,000 marine species known or likely to be present in Australian waters, of which 130 are introduced and 58 listed as threatened (Butler and others 2010). This marine biodiversity is particularly susceptible to climate change impacts in coral reef, coastal wetland, estuarine, intertidal and rocky reef habitats (Brierley and Kingsford 2009; Russell and others 2009; Hughes 2011). The rapid rate of change in the physical environment may be beyond the capacity of some species to adapt in a timely manner; survival will be dependent on management interventions that seek to reduce non-climate stressors and increase resilience (Crowder and others 2006; Brierley and Kingsford 2009; Veron and others 2009; Stein and others 2013).

Understanding resilience problems in marine sustainable resource use and biodiversity conservation can be significantly advanced through systems approaches - in particular social-ecological system analyses (Lebel and others 2006; Folke 2010; Lockwood and others 2012). Gallopín (2006: 294) define a social-ecological system, that can be specified for any scale from local to global, to include the 'societal (human) and ecological (biophysical) subsystems in mutual interaction'. A system perspective supports a spatially and temporally integrated consideration of ecological, social, economic and policy influences on marine system dynamics in a way that can inform response strategies (Pollnac and others 2010; Kittinger and others 2012; Schlüter and others 2012; Ban and others 2013). Systems understanding can also enhance capacity for collaboration and shared decision making (Biggs and others 2011). Collaborative networks of stakeholders who pool information and work together on response strategies is an appropriate pathway for dealing with the complexities of sustainable resource use (Armitage and Plummer 2010). Building shared understanding at the science–policy interface through knowledge transfer and consensus building is particularly salient in the context of climate change (Bodin and Crona 2009; Falaleeva and others 2011; Cvitanovic and others 2015).

Many individual researchers are contributing to our growing understanding of both impacts and potential responses, but coordinated programs offer the potential for greater insights, particularly in large and diverse regions such as Australia (Carpenter and others 2012; Frusher and others 2014; Holbrook and Johnson 2014). A recent program initiated in Australia was successful in linking the resources of a number of research providers to collectively and collaboratively address challenges associated with marine climate impacts and adaptation. The Fisheries Research and Development Corporation (FRDC), one of the key Australian agencies responsible for commissioning research to assist in the management of the fisheries and aquaculture resource for ongoing sustainability, was the lead partner. Collaboration with the then Department of Climate Change and Energy

Efficiency and other Government investors led to the design and implementation of a $9M program of research: the Climate Change Adaptation – Marine Biodiversity and Fisheries initiative (Creighton 2014). The program design recognised that global approaches and actions to mitigate anthropogenic climate change could, at best, only slow the rate of change in the physical environment. Therefore the investment approach for this research program was to examine how Australia, through its various policy frameworks and management mechanisms, can best adapt to a changing climate (Mapstone and others 2010). As context, there was already substantial biophysical research available both regionally and globally defining the likely extent of climate change, the mitigation imperative and the broad implications of a changing climate (e.g. Poloczanska and others 2007; Mapstone and others 2010; Frusher and others 2014). Twenty-five research projects were funded under the initiative. Reflecting the diversity, size and complexity of Australia, projects encompassed tropical to temperate systems, considered multiple habitats (estuaries, wetlands, coastal and oceanic systems) and included aquaculture, commercial and recreational fisheries, and marine biodiversity governance, planning and management. All projects were required to include an assessment of the opportunities out to 2030 for adaptation through improved policy frameworks and management mechanisms.

Here, we distil from this portfolio of research a suite of key elements required of policy and management to adequately adapt and respond to a changing climate. These elements, structured into three phases, are presented as a checklist to guide reform and assess progress towards a climate-ready marine future. To illustrate the application of these elements we use Australian examples to indicate key areas of investment needed to better position Australia to respond to a changing climate, and more generally to global change. Our findings are directly relevant and transferable to other global regions, providing guidance for marine managers and stakeholders as they prepare for a future under climate change.

PHASES IN ESTABLISHING ADAPTATION RESPONSE CAPABILITY FOR MARINE POLICY AND MANAGEMENT

Management of marine resources for conservation and sustainable harvest is more challenging than ever. A range of anthropogenic activities has triggered environmental changes that greatly exceed natural background fluctuations (Rockström and others 2009; Steffen and others 2011; Steffen and others 2015). Most pervasive is a changing climate resulting in altered physical conditions in many marine regions around the world (Doney and others 2012; Hobday and Pecl 2014). Concomitant changes in distribution, abundance, physiology and phenology are already evident for many marine species (Doney and others 2012; Poloczanska and others 2013). Nowhere is this change more evident than at coastal margins where observed and predicted increases in temperature, acidity, UV radiation, nutrient concentrations, fishing pressure, coastal development, frequency and duration of hypoxic events are well documented (e.g. Hoegh-Guldberg and others 2007; IPCC 2013). The speed of change in average environmental conditions and the increased frequency of extreme events (heat waves, hypoxia) may exceed the potential of marine organisms for tolerance or adaptation (Koehn and others 2011; IPCC 2014). Moreover, global change is multifactorial and the compound action of several stressors is often synergistic (Brown and others 2013). Global change will also lead to altered adaptation responses in human systems, economic opportunities and conservation priorities, all of which will require revised policy frameworks and management approaches.

Systems thinking demonstrates that climate (and its impacts) is but one of many issues that might contribute to policy and management decisions. Indeed marine management, by virtue of being multi-objective and needing to meet diverse and sometimes competing user needs, is best served by a multi-component approach that incorporates climate as one of many issues to be accommodated. Responses to address the challenges of climate change will range from those that are minor or incremental through to those that involve more radical shifts in resource management and utilisation (Stafford-Smith and others 2011; Park and others 2012; Wise and others 2014). Accordingly, our synthesis recognized three interlinked phases of the adaptation process. Historically, management of marine biodiversity and resources has not necessarily or typically taken a systems view. Thus, there is a need to ensure that policy, management and institutional structures are better aligned so that there is a solid platform on which to develop adaptation responses (Frusher and others 2014; Wise and others 2014). We term this first necessary phase 'preconditioning'. Once policy and management structures are aligned, 'future proofing' of systems can include the knowledge assimilation and building of conceptual understanding required to begin operational processes and direct actions on the ground. Elements under this category highlight the need for integrated systems thinking and approaches, based on an interdisciplinary and socio-ecological systems view. Lastly, to facilitate the sustainable use and conservation of living marine resources into a vastly different future, both 'transformation and opportunity' need to be considered. In the next section, we summarise findings from the research program, and from these inductively develop thirteen elements across these three phases that serve to guide and assess adaptive policy and management reforms.

IMPERATIVES FOR ENHANCED MARINE BIODIVERSITY AND FISHERIES MANAGEMENT – A CLIMATE CHECKLIST

Based on review of the portfolio of research projects (Table 1), supporting literature, and the experience of the authors, we derived a climate checklist consisting of 13 "elements" spread across the three phases (Table 2). These elements were derived and then consolidated by considering the key findings and recommendations that were made in each of the projects. The 25 projects spanned seven different areas: oceanographic environment (n=1), aquaculture and fisheries (n=11), marine biodiversity and fisheries (n=8), carbon sequestration (n=1), coastal tourism and amenity (n=1), community-led adaptation (n=1) and knowledge (n=1). Within each project, between four and 13 of the elements were addressed, with an average of nine elements for the fisheries and biodiversity projects. Each of the elements was addressed by an average of 16 projects, with a range between 9 and 24 projects (Element 11 and Element 1, respectively) (Table 1). In the remainder of this section, we describe each of these elements, which are designed to guide and assess policy and management reform, with a particular focus on adaptation capacity for dealing with climate change. We note that elements in each phase may need to be re-assessed over time to ensure alignment to deliver the expected benefits.

Our suite of elements provides an assessment of the *preconditioning* necessary to enable improved policy and management. Firstly, *policy and management need to respond to changing social-ecological conditions, so interventions must be as dynamic as the systems they seek to influence.* Inshore, coastal and marine systems are dynamic, yet many current management practices are spatially static (Hobday and others 2014a). Our responses to a changing and more variable climate must also become dynamic and flexible (Grafton 2010). Marine examples are rare, but an exemplar is the operational use of dynamic spatial management to regulate fisher access to regions off the east coast of Australia (Hobday and Hartmann 2006; Hobday and others 2010). Short-term management responses to extreme events, such as modified regulations, spatial closures, and redistribution of activities can also facilitate recovery for impacted ecosystems and dependent industries (Hodgkinson and others 2014), and could be developed strategically rather than following an event (GBRMPA 2011).

Both fisheries and conservation management must recognise the dynamic nature of inshore and marine resources. There is no static or set of climax communities that we must strive to protect. Our adaptive interventions must focus on seeking to ensure greater resilience. Ecosystems must have the greatest capacity possible to sustain shocks such as extreme climate events while recognising that there will be changes such as those bought on by a changing and more variable climate that are beyond our ability to readily reduce.

Secondly, *action for climate adaptation must be a part of larger social and economic adaptation to changing circumstances.* The drivers of social and governance change are broader than just climate-related issues. Indeed in project discussions with fishers and marine managers, climate change adaptation was rarely the most important influence on practice change and future planning (Pecl and others 2014a). Other issues such as changing markets, increasing input costs, availability of labour, community attitudes, and policy imperatives for nature conservation, were often of more immediate concern (Lim-Camacho and others 2014; Fleming and others 2014). Climate change adaptation is therefore best undertaken as part of the overall management process for inshore, coastal and marine social-ecological systems.

In a similar context, most projects found that *climate policy should be implemented as part of integrative, multi-objective policy and management (#3).* Marine policy approaches generally include concepts such as ecosystem-based management, managing complexity, integrated monitoring and assessment systems for sustainable economic yield, fostering regional economies and ensuring food security (Grafton 2010; Bell and others 2011). Recognition of the effects of a changing climate must be integrated into this complex policy agenda. In the Whitsundays region of the Great Barrier Reef, for example, while current governance arrangements have good adaptive capacity in many respects, the critical areas for improvement are (i) engagement of local government, catchment management authorities and local advisory bodies in integrated coastal and marine planning and management, and (ii) improved integration and coordination between relevant agencies, and between government levels, especially integration of conservation and fisheries management (Davidson and others 2013).

Fourthly, *in responding through management interventions to changing interactions it is essential to include climate influences.* Australian fisheries management, for example, already seeks to take account of multi-species and species–habitat interactions (Hobday and others 2011). Climate is part of what influences these interactions so any changing climate and its impact on interactions will also need to be recognised (Hobday and others 2008; Plagányi and others 2013). Commercially targeted annual prawn stocks such as School Prawn, *Metapenaeus macleayi*, Banana Prawn (*Fenneropenaeus merguiensis*) and Tiger Prawns (*Penaeus esculentus* and *Penaeus semisulcatus*) all respond and interact to rainfall and runoff in the proceeding 8 to 10 months of juvenile phases before the stock enters the fishery, and such leading indicators can be used to plan fishing management and strategies (Plagányi and others 2013).

Within the broad phase of 'future proofing', and intersecting with the preconditioning phase, is recognition of the issues of resilience, scale and relevance, as described in the next four elements. If we are to minimise any negative impacts of change then *fostering resilient healthy ecosystems is an imperative for policy and management (#5).* If we repair and then protect and sustainably use inshore and marine resources then productive healthy ecosystems will be more resilient to perturbations such as extreme events (Miles 2009). Extreme events include marine heatwaves, cyclones, terrestrial droughts (and therefore lack of freshwater run-off to foster productivity in our estuarine and nearshore zones) and terrestrial floods (and often major fish kills from deoxygenation, massive increases in sediment load and sudden changes to water chemistry such as acidic effluent from drained wetlands that accompanies floods). Repairing for increased resilience is a key priority for future proofing investment. Globally, the most valuable marine habitat and biodiversity resources are coastal resources, especially estuaries, floodplain wetlands and nearshore habitats (e.g. Diaz 2002; Vaquer-Sunyer and Duarte 2008; Creighton 2013a, b; Creighton and others 2015). These inshore and nearshore resources are also most at threat from extreme climate events (Dichmont and others 2014). Increased focus on investment in repair will enhance resilience and optimise the multiple public benefits derived from these inshore and coastal resources.

Healthy, resilient systems also require relevant management approaches, as represented by the next two elements in this phase – *policy and management must address spatial and temporal scales that match the values and issues of concern (#6)*; and building further on the requirement for resilient healthy ecosystems, *catchment management is essential for positive marine outcomes (#7).* To illustrate, current fisheries management is usually sub-divided into smaller jurisdictional regions rather than operating at the geographic scale of the stocks we seek to manage (Link and others 2011). In Australia, this larger scale management might be facilitated through recognition of three broad regions that approximate the ranges of much of our living marine resources – south-east, tropical and western (Hobday and others 2008). Climate is one of the drivers towards this more holistic approach to cross-jurisdiction marine management. Catchment management also represents a holistic approach, as marine, estuarine and riverine ecosystems are connected with flows of material and biota. The health of these systems is adversely impacted by effluent from catchment uses (Creighton 2013a, b). Climate change and the increasing likelihood of extreme flood events with ability to dump higher loads of effluent in receiving waters makes it even more imperative to reduce catchment effluent – sediments, nutrients and poisons, all of which adversely impact on the productivity, health and resilience of riverine, estuarine and marine ecosystems.

Lastly in this phase are elements related to protective management such as setting aside areas for marine parks and species-specific conservation – *in responding to threatening processes, it is essential to ensure ecosystem integrity (#8);* and recognition that specific approaches will be required at the species level – *site- and species-specific strategies are be essential (#9).* Conservation management of marine systems should focus on ecosystem integrity including stocks, flows, fluxes and ecosystem interactions and must seek to minimise any threatening processes that impact on ecosystem integrity. Providing marine park protective management for a suite of representative ecosystems, bioregion by bioregion, without simultaneously seeking to minimise the impact of all threatening processes including climate impacts, will prove to be insufficient for biodiversity conservation. A changing climate will change the impact of many threatening processes. A changing climate also demonstrates the potential inadequacies of static management responses such as hard and fast marine park zonings and boundaries. For individual species, a changing climate will impact on key species of high conservation value such as seabirds and marine mammals (Chambers and others 2014; Hobday and others 2014b). Site- and species-specific management to minimise the impacts of a changing climate is essential if we are to conserve these populations, and their roosting or resting, breeding and feeding habitats. A focus for these direct interventions will be iconic species and habitats, which also play an important role in communicating the threats of climate change to the general public (Ochoa-Ochoa and others 2013).

However, in any changing system there will be winners and losers – interventions will not be possible for all impacted species and ecosystems. There will be opportunities and so *changes brought about by a changing climate must also be assessed for beneficial opportunities*

(#10). Some commercially valuable species will be advantaged by a changing climate. For example, Pecl and others (2014b) and Robinson and others (2015) suggest a southward range extension of Eastern Rock Lobster (*Sagmariasus verreauxi*) range, while the productive fishery region for the Southern Rock Lobster (*Jasus edwardsii*) range may contract southward. Some marine production systems will be benefited by climate change. For example, Jerry and others (2014) project a southward extension of suitable environments for Barramundi (*Lates calcarifer*) aquaculture whereas for other species production systems may be challenged (e.g. suitable inshore aquaculture areas for Atlantic Salmon (*Salmo salar*) may decline (Battaglene and others 2008; Spillman and Hobday 2014). A positive facilitative approach to industry development is essential and will be better informed through value chain analysis and the identification of key opportunities (Lim-Camacho and others 2014; Plagányi and others 2014).

Similarly, to build on the opportunities for shifts in productivity there will need to be changes to foster better management of any particular fishery stock or species population - *in responding to increased climate variability and change a transition towards flexible total stock or population management systems is essential (#11).* In particular, a changing and more variable climate will lead to changing and more variable fish stocks. Populations will change in abundance, composition (age classes, etc.) and location. Incorporating climate impacts in fisheries management requires management processes, opportunities and controls to incorporate temporal and spatial variations in the target stock or the ecosystems that sustain that stock. Early detection of stock changes is essential as spawning stocks can become depleted if there is a downturn in recruitment that is undetected and fishing pressure is maintained. The Western Rock Lobster (*Panulirus cygnus*) fishery has avoided any large reduction in spawning stock because of the early intervention on the decline in recruitment (Caputi and others 2014).

By comparison, and to demonstrate the importance of both the time dimension and the need to focus on underlying causal mechanisms for effective management, early fisheries management intervention to close the Shark Bay Southern Saucer Scallop (*Amusium balloti*) fishery did not avoid a major reduction in the spawning stock (Pearce and others 2011). This was because the severity of the recruitment downturn was due to mortality of adults that followed an extreme runoff event and high sediment loads to Shark Bay, which was beyond the influence of any fisheries management intervention. In this case, sustainable catchment management that recognised the value of the downstream fishery resource would have ensured adequate groundcover of the catchment land, thereby reducing the likelihood of a significant rain event being accompanied by extensive soil erosion.

The last two elements deal with the opportunities for marine systems, and our uses of marine systems, to contribute to the overall climate change mitigation agenda. While adaptation remains the primary focus for the regional fishery and management sector, a number of Australian marine projects recognise that *policy and management must take advantage of the key role marine ecosystems can have in carbon sequestration (#12).* Coastal, nearshore marine and estuarine ecosystems, by virtue of being the most productive of the world's ecosystems are also the highest per hectare sequesters of carbon. Lawrence and others (2012) detail that Australia's coastal wetland ecosystems sequester and bury carbon at rates of up to 66 times higher and store 5 times more carbon in their substrates than those of our terrestrial ecosystems, including forests, on a per hectare basis. Taking up less than 1% of landmass, the average national annual carbon burial of coastal ecosystems may account for 39% of that for all ecosystems (183.2 Tg (million tonnes) CO_2 eq yr-1 of a total of 466.2 Tg CO_2 eq yr-1, Lawrence and others 2012). Yet, Australia is estimated to be losing its coastal wetland ecosystems at an annual rate of 0.01-1.99% for mangroves, 1.17% for saltmarsh and 0.05% for seagrass (Lawrence and others 2012). There is also potential for substantial gains in carbon sequestration by the reinstatement of tidal flows and habitat repair of degraded coastal wetland ecosystems, especially Australia's floodplain wetland resources that are currently wastelands, drained and/or levied off from tidal flows but not supporting any viable land uses. The next steps from a policy perspective for Australia and indeed internationally is for coastal ecosystems to be incorporated into National Carbon Accounts. Flow-on benefits are likely to be higher levels of protection for remaining nearshore marine and estuarine ecosystems and where possible their reinstatement through repair works.

Lastly, and similar to earlier elements in terms of the need for actions on adaptation to be multi-objective and multi-faceted, *carbon sequestration in marine systems is best done as part of a multi-objective approach (#13).* Investments in climate change mitigation could most usefully focus on those opportunities that also provide multiple benefits to the global community and local economy. From a marine perspective, repairing coastal ecosystems of seagrasses, mangroves, salt marshes and floodplain wetlands globally provides not only the highest per hectare carbon sequestering opportunity but also deliver outcomes for local to regional food security, employment and biodiversity.

KEY PRIORITIES FOR MARINE POLICY DEVELOPMENT AND MANAGEMENT

To illustrate how best to apply these thirteen elements incorporating climate change concerns into marine policy and management, we group recommendations connected to the elements within three phases of activity. From a preconditioning perspective we need to know more about our marine systems, devise and implement strategies based on an understanding of total populations and formulate more flexible policy to achieve conservation and fisheries sustainability goals. Pecl and others (2014a) detail the need for enhanced stock assessment methods and for the findings to be rapidly incorporated in management. Smarter and real-time stock assessment and population predictions will foster a more profitable and sustainable fishing sector. To achieve improved stock assessment we need cheaper and more outcome-orientated monitoring systems that calibrate projections of change, provide ongoing population information and assess the effectiveness of our management. Improved monitoring should also rapidly identify when there are major shifts in our populations or systems, foster "double loop learning" so that we learn from experiences and revise our understanding (Lockwood and others 2012; Hodgkinson and others 2014) and be incorporated within a risk management philosophy. All marine nations must prioritize limited resources for monitoring and assessment, so that a risk management approach to minimise unwanted outcomes while still ensuring effective investment is essential (Pecl and others 2014b).

For many of the short-lived fisheries target species such as all prawns (Poloczanska and others 2007) and squid (Pecl and Jackson 2008), annual populations vary markedly and will do so more in the future. This is a direct consequence of increasingly variable climate, rainfall, run-off and sea surface temperatures. Influence on population dynamics will also extend to the estuary and nearshore dependent species such as Barramundi, Sea Mullet (*Mugil cephalus*) and Mulloway (*Argyrosomus japonicus*). Changing eddy and sea surface temperature dynamics will affect marine target species such as Southern Bluefin Tuna (*Thunnus maccoyii*) (Hartog and others 2011). Improved stock prediction, linked to climate and all other key variables will ensure effort can then be better matched to productivity. This will lead to increased profitability and sustainability by better matching annual and varying sustainable economic yields to the stock available.

Several projects including #9 Caputi and others (2014), # 11 Welch and others (2014), #12 Creighton and others (2013) and #13 Pecl and others (2014a), stressed the need for policy development so that biodiversity conservation and fisheries management is based on total populations, rather than jurisdictional legacy (Link and others 2011). Marine and inshore fisheries target species such as Snapper (*Pagrus auratus*), Spanner Crab (*Ranina ranina*), Eastern and Southern Rock Lobsters are already documented as changing range (Last and others 2011; Robinson and others 2015) and entire stocks of any species are under the influence of a changing and more variable climate. Their recruitment, growth, geographic range and spawning processes have no regard for jurisdictional boundaries or fishing zones. Likewise seabirds and marine mammals are not constrained to particular jurisdictions. With increasingly variable populations, moving to whole-of-stock / population monitoring and management, whatever the jurisdiction, is one of the next major steps in both fisheries management and species conservation. Testing cross-jurisdictional policy, practice and operationalizing multi-species and population rather than jurisdiction management will take time and will need to be carefully underpinned by research. Equally important, as part of the management decision-making process, there is a need to document and incorporate in policy decisions not only production–catch issues but also consider challenges along the supply chains (Fleming and others 2014; Plagányi and others 2014).

Related to this is the need to encourage more flexible conservation and fisheries management. We need to better understand the relevant subsystem, surrounding biophysical conditions and ecosystems, to understand and respond to changing community perspectives and expectations and develop policy and management strategies accordingly. Compare this to current conditions where much of current fisheries and biodiversity management is strongly focused on inputs (e.g. allowable number of fishing dories, or rigid take- or no-take zones within parks, roosting and breeding refuges and other spatial entitlements and zones). Some Australian populations are at least 'sub-global' such as bluefin tuna, sea turtles, migratory seabirds and mammals that spend part of the year outside Australian waters. A stronger focus on outputs and outcomes responding to and taking account of more variable populations, stocks, flows and fluxes will be essential if we are to ensure the sustainability of inshore and marine resources.

In project #19, Davidson and others (2013) and Haward and others (2013) evaluated existing marine governance and noted that rigid boundaries for marine parks or for fisheries entitlements have limited relevance when stocks are fluctuating and moving in range. Flexible approaches accept that social-ecological systems are managed with incomplete knowledge so that management authorities need flexibility to adjust strategies, including management zones and marine use boundaries, based on the results of monitoring (Lockwood and others 2012). Audits of management arrangements and how they do or do not foster flexibility in management together with improvements in policy, management arrangements and regulations will assist all marine managers in their tasks to ensure healthy biodiverse marine environments and profitable fishing industries. Pecl and others (2014a) (project #13) benchmarked several Australian fisheries against a set of governance attributes covering accountability, planning, transparency, incentives, adaptability and knowledge. With respect to snapper fisheries, for example, the presence of attributes likely to provide resilience to climate change vary among jurisdictions, while the governance system for blue grenadier includes many of the attributes likely to provide resilience to potential reductions in future recruitment or shifts in recruitment dynamics. It is also important that assessments, while providing for accountability, include a focus on long term outcomes (Lockwood and others 2010).

Recognising that gaining additional investment in marine policy and management is always challenging, we suggest the best approach to future proofing is to focus on strategies with multiple beneficiaries. These include multi-objective multi-sector strategies such as investment to repairing nearshore and estuarine habitat to reinvigorate inshore productivity and foster resilience to extreme events; single sector strategies with multiple benefits such as fishing bycatch reduction and pest management on islands; and single objective multi-benefit strategies such as improved weather and climate forecasting.

Creighton (2013a, b) took the view that one of the priority immediate actions to buffer the systems to a changing and more variable climate must be to *reinvigorate inshore productivity by repairing habitat*. As just one example, the 2013 rain event on the Clarence estuary, northern NSW led to the death from deoxygenated acidic run-off of all benthos from Grafton to Yamba, essentially the entire estuary of about 90 km in length. Sydney Rock Oyster cultivation in NSW is now about 40% the 1970s production at least in part due to deleterious catchment run-off, especially derived principally from the drainage and floodgating of major wetland resources (Kirkendale L, Winberg P, Rubio A, Middelfart P, Unpuplished Manuscript). Even the hardier and more rapid growing Pacific Oyster is facing increasing kills with run-off events. The decline in Sydney Rock Oyster yield has occurred despite ongoing improvements in growing technology, enhanced genetic stock, and increased consumer demand and price. Because of habitat loss and deleterious water quality, as well as abandoning oyster leases in major floodplain estuaries, the industry has replaced Sydney Rock Oyster with the more resilient Pacific Oyster (*Crassostrea gigas*). In turn, the Pacific Oysters that came to replace Sydney Rock Oysters have been affected by the virally-mediated Pacific Oyster Mortality Syndrome. There have been major kills of the more resilient Pacific Oysters during the 2012 and 2013 floods with their accompanying poor water quality (Paul-Pont and others 2013, 2014). Redesigning catchment landscapes and repairing key components of fisheries and biodiversity productivity with the flow-on multiple public and private benefits they all provide is essential if we are to equip our inshore resources with resilience to more frequent extreme events.

Approaches that target a single species can also be effective by delivering multiple benefits to the ecosystem or to related industries. For example, to improve population persistence of threatened seabirds under climate change, pest eradication on breeding islands (e.g. rats) may allow other species to thrive and also offset population losses incurred as a result of other activities (e.g. fisheries bycatch) (Wilcox and Donlan 2007). Single species intervention in response to climate change risk can also have wider effects when the focal species is a keystone species or major habitat architect (e.g. *Centrostephanus*). In single species or habitat interventions, attention to any additional benefits can help prioritize efforts (Hobday and others 2014b).

Davidson and others (2013), in exploring marine governance (project #19), compared and contrasted three case study areas and the effectiveness of the institutional frameworks currently in place. Institutional frameworks for multi-objective marine resilience are key to improved marine management. Much governance is single objective in focus and there are strong institutional dysfunctions between agencies. There is also no coherent funding model to cover the massive costs of marine management and monitoring across all sectors of marine use. A multi-source strategy is required, with consideration given to a mix of government, private sector and philanthropic sources managed as endowments through mechanisms such as independent trusts (Lockwood and Quintela 2006; Lockwood and others 2012). Part of the process is to take account of and assimilate information from successful examples (e.g. Georgia Basin, Washington state, US; and Puget Sound, Canada trans-boundary region) and then modify these as part of transferring improved governance to suit institutional, social and economic settings. Most importantly, without understanding the social and economic drivers in marine social-ecological systems, it is difficult to deliver on 'triple bottom line' environmental, social and economic outcomes. Regional marine and landscape planning and management, with a strong focus on the multiple benefits streams of food security, sustainability, conservation and increased productivity, are likely to be welcomed by the Australian community.

While climate scale forecasting to the end of the century has dominated much of the thinking around impacts and responses (Hobday and Lough 2011; Stock and others 2011), shorter time scales are also relevant (Hobday and others in press). Improved marine weather and climate forecasting together with specific enhancements such as ocean current and ocean eddy forecasting can support a host of marine user decisions. These include ship movements, defence, fisheries, oil and natural gas extraction. The increasing variability and changes in ocean conditions, the increased dynamics of nearshore eddies and currents and changes to marine biodiversity on short-term time scales makes accurate forecasting even more important for all marine users. With ocean conditions influencing much of the terrestrial weather patterns, flow-on benefits to land weather services would also be substantial. Seasonal forecasting has been implemented in several Australian conservation (Spillman and Alves 2009), fishery (Hobday and others 2011) and aquaculture (Spillman and Hobday 2014) sectors, and represents a useful stepping stone to longer decision making, by familiarizing decision-makers with the use of forecasts on a time scale that allows the consequence of a decision to be observed (Hobday and others in press).

With regard to transformational change, some of the best examples are linked to the carbon mitigation and energy sectors. Marine systems can contribute globally to smarter energy use and to mitigation. Fuel is a major part of the input costs for all wild fishery (Pelletier and others 2014), marine park and fisheries enforcement vessels and a high part of the costs of undertaking marine research. In some maritime nations such as New Zealand, specific initiatives have targeted fuel efficiency (New Zealand Seafood Industry Council 2010). This includes incentives for installing fuel flow meters, training in smarter boat use, systems for sea 'mooring' on the fishery, more fuel efficient gear such as otter boards and nets and designs that further reduce by-catch. Initiatives targeted on more efficient marine practices would yield multiple dividends in increased profitability, reduced carbon footprint and reduced adverse impacts on such as by-catch and habitat. Similarly, energy is a major cost input to virtually all aquaculture systems. As the price of energy increases so do aquaculture industry costs and therefore reduced profit margins. Technical support for energy efficiency audits, assistance in developing the break even business cases for investment in energy miser paddlewheels and pumps or revised recirculation systems and energy efficiency training would foster a more profitable, reduced energy consuming aquaculture industry. Integrated aquaculture being carbon sequestration and energy transfer systems on large scale require further research and development. A good example is macro-algae production linked to aquaculture or other industrial sources of nutrients and carbon dioxide for a new marine biomass platform in Australia in both onshore (FAO 2009) and offshore systems (Troell and others 2009). Such production can even counteract localized effects of ocean acidification (Jiang and others 2012).

Finally, from a mitigation perspective, policy and strategies to implement "blue carbon" (e.g. Nelleman and others 2009; Siikamäki and others 2013) can complement the adaptation focus. As an example, Australia's coastal wetlands, seagrasses, mangroves and salt marshes comprise less than 1% of the landscape yet sequester over 39% of Australia's carbon (Lawrence and others 2012). There are substantial opportunities for these areas to contribute to a carbon economy. These marine environments need to become part of all National Carbon Accounts. Investment for carbon mitigation would also have the flow-on benefits of improved fisheries habitat, flood control, and infrastructure as well as increasing biodiversity (Lawrence and others 2012).

CONCLUSION

Climate change is leading to a range of changes in marine systems, influencing the distribution and abundance of exploited species and conservation-related species and habitats. Adaptation represents a regional scale response to climate change where actions will have direct benefit. However, to respond to the threats and opportunities posed by climate change, policy and management must change in order to facilitate the development of adaptation options at a range of scales. If the alignment of policy and management is not compatible with responses, then **preconditioning** changes must first occur. Our checklist presents the elements that poorly prepared governance systems must first address, before the **future**

proofing activities can be widely initiated. These activities are generally implemented by single agencies guided by the higher order policies. Some can be initiated immediately, while others will require greater **transformation**. Transformational opportunities where the benefits of action result in even greater feedback and reinforcement of the benefits are particularly important, and will require sustained effort to achieve. If this identification of policy and management elements as provided in our checklist is useful, we expect that success would be visible by refinement of higher level policy documents, such as national action plans. At the future proofing stage, examples where fisheries and conservation agencies implemented test cases for particular species or systems that could be easily addressed would begin to emerge (Alderman and others, Unpublished Data). Transformation change will require greater coordination between disparate research fields, and resolution of issues that appear to be opposed in different sectors. Adaptation to climate change will not be easy in all cases, and so attempts to begin with the easier elements, learn from mistakes and to share these lessons will be critical.

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Table 1. Project findings and implications for climate change adaptation. Elements 1-13 are listed in Table 2. A tick (√) indicates that the project identified the element as important. Project reports for each of these are available from www.FRDC.com.au.

Project focus	Project number and title	Relevant finding	Element 1	Element 2	Element 3	Element 4	Element 5	Element 6	Element 7	Element 8	Element 9	Element 10	Element 11	Element 12	Element 13
Oceanographic Environment	1. Understanding the biophysical implications of climate change in South Eastern Australia: Modelling of physical drivers and future changes	Development and improvement of the existing physical models is not a roadblock to further fishery adaptation planning.	√			√		√							
Aquaculture	2. Ensuring the Australian oyster industry adapts to a changing climate: a natural resource and industry spatial information portal for knowledge and informed adaptation frameworks	There is a common need to access information that is both locally relevant and nationally positioned.	√	√	√	√	√	√	√					√	√
Fisheries and Aquaculture	3. Development and testing of a national integrated climate change adaptation assessment framework	Adaptation frameworks should foster decision strategies based on a combination of fishery performance and human socioeconomic performance	√	√	√	√	√	√		√		√			
Fisheries and Aquaculture	4. Vulnerability of an iconic Australian finfish (Barramundi, *Lates calcarifer*) and related industries to altered climate across tropical Australia	Both wild caught and cultured Barramundi are likely to extend south in range and total population and resource planners should begin to implement various scenarios into fisheries planning models.	√	√	√	√	√	√	√	√		√	√		
Fisheries	5. Growth opportunities for Australian fisheries and aquaculture under climate change	Stronger connection between different sectors and segments in the supply chain confers resilience.	√							√	√	√	√	√	√
Fisheries	6. Risk assessment of impacts of climate change for key species in South Eastern Australia	Fisheries managers need to be proactive in positioning themselves to undertake a strategic and structured approach to adaptation planning.	√	√	√	√	√	√	√	√	√	√	√		
Fisheries	7. Identifying management objectives hierarchies and weightings for four key fisheries in South Eastern Australia	It is important to articulate the objectives of fisheries management as an early step in fisheries adaptive management and of integrating climate change driven changes into this process	√	√	√	√	√	√		√	√	√		√	√

Fisheries	8. Identification of climate-driven species shifts and adaptation options for recreational fishers: learning general lessons from a data rich case	Long-term fisher collected data sets offer opportunities to investigate complex interactions between species-level change, environmental signals and anthropocentric impacts.	√	√		√		√	√	√		√			
Fisheries	9. Management implications of climate change effect on fisheries in Western Australia	Monitoring of key environmental variables and habitat is essential to enable early detection of changes in abundance and therefore allow for proper assessment and management recommendations before fishing takes place.	√	√	√	√	√	√	√			√	√		
Fisheries	10. Effects of climate change on reproduction, larval development and population growth of coral trout (*Plectropomus* spp)	Recognising the sensitivity of coral trout to increasing temperature, ocean acidification and climate – induced habitat degradation the imperative is to understand how these affect will manifest in terms of the productivity and sustainability of wild fisheries.		√		√	√	√		√			v		
Fisheries	11. Implications of climate change on fisheries resources of northern Australia – vulnerability assessment and adaptation options	Appropriate adaptation must include detailed analysis of options; prioritisation of adaptation responses; impact assessment and profitability analysis for indigenous. Recreational and commercial fishers; and detailed specification of the pathways and actions to be implemented.	√	√	√	√		v	√	v		√	√		
Fisheries	12. Implications of climate change for recreational fishers and the recreational fishing industry	Management activities that assist in ensuring resilience of fish populations will be a useful first strategy in responding to a changing climate	√	√	√	√	√	√	√	√		√	√	√	√
Fisheries	13. Preparing fisheries for climate change – assessing alternative adaptive options for four key fisheries in South Eastern Australia	The design, application and review of management strategies will require improved understanding of biology such as recruitment dynamics and ecology; increased monitoring of key biophysical attributes and stocks to populate models; harvest strategies that deliver sustainable economic yield; and extension of model outputs into management decision making.	√	√	√	√		√		√	√	√	√		

Fisheries and Marine Biodiversity	14. Potential futures for Australia's South Eastern marine ecosystems, quantitative Atlantis projections	Integrative adaptive management across all users of the marine and coastal environments is the most effective means of maintaining sustainable, desirable and productive marine ecosystems under all levels of global change.	√	√	√	√	√	√	√	√	√	√	√	√	√
Fisheries and Marine Biodiversity	15. Revitalising Australia's Estuaries	The return on investing in restoration ecology of Australia's coastal ecosystems well exceeds the benefits accrued from all prior major Australian initiatives in environmental repair.	√	√	√		√	√	√	√		√		√	√
Fisheries and Marine Biodiversity	16. Estuarine and nearshore ecosystems – assessing alternative adaptive management strategies for the management of estuarine and coastal ecosystems	Ensuring ecosystem robustness and resilience are maintained at whole-of-resource scale is essential to ensure public good outcomes.	√	√	√	√	√	√	√	√	√	√		√	√
Marine Biodiversity	17. Pre-adapting a Tasmanian coastal ecosystem to ongoing climate change through reintroduction of a locally extinct species	A comprehensive decision framework is essential to assess conservation translocation proposals	√	√	√		√	√		√	√	√			
Marine Biodiversity	18. Human intervention options for seabirds and marine mammals under climate change	Direct interventions exist and must be tested for efficacy.	√		√	√	√								
Marine Biodiversity	19. Changing currents in marine biodiversity governance and management: responding to climate change	Common challenges are improving knowledge of the social-ecological system; stakeholder communication and information; improving capacity to deal with uncertainty and complexity; preparedness for change; lack of broad public and political support for the values of marine biodiversity; and integration and coordination gaps amongst and across government agencies.	√	√	√		√	√	√	√	√			√	√
Marine Biodiversity	20. Adaptive management of temperate reefs to minimise effects of climate change: Developing new effective approaches for ecological monitoring and predictive modelling	Long-term monitoring is essential for detecting and describing change and informing appropriate management responses.	√		√		√	√	√	√	√				√

Marine Biodiversity	21. Adapting to the effects of climate change on Australia's deep marine reserves	Adaptation strategies involving assisted translocation and the use of artificial substrates may be required to conserve the cold water coral reefs that characterise seamounts in the South East Marine Reserve.	√		√		√	√		√	√				
Carbon sequestration	22. Comparative sequestration and mitigation opportunities across the Australian landscape and its land uses	Carbon storage and sequestration in coastal ecosystems provides an additional tool to mitigate globally; an opportunity to strengthen socioeconomic resilience of Australia's coastal communities and industries; avoids significant emissions from ecosystem degradation; and supports wetland conservation efforts.	√	√	√		√	√	√	√		√		√	√
Coastal tourism and amenity	23. Beach and surf tourism and recreation in Australia: vulnerability and adaptation	Coastal managers will need to utilise a menu of adaptive management strategies to minimise the economic losses associated with climate change impacts on beaches.	√	√	√			√			√	√			
Community led adaptation	24. A marine climate change adaptation blueprint for coastal regional communities	Key components of community response include working within a boundary organisation; integrating climate change with other stressors; bringing together biophysical and human dimensions; being inclusive and encompassing the entire marine community; combining qualitative and quantitative approaches; and ensuring access to up to date information and research findings.	√	√	√		√	√				√		√	
Knowledge	25. Climate Change Adaptation: Building community and industry knowledge	To increase knowledge uptake requires specialised understanding and approaches	√	√	√			√							

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Table 2. Summary of the elements described in the text for guiding and assessing marine policy and management change, in each of three phases

Phase	Element
Preconditioning	1. *Policy and management need to respond to changing social-ecological conditions, so interventions must be as dynamic as the systems they seek to influence.*
	2. *Action for climate adaptation must be a part of larger social and economic adaptations to changing circumstances.*
	3. *Climate policy should be implemented as part of integrative, multi-objective policy and management.*
	4. *In responding through management interventions to changing interactions, it is essential to include climate influences.*
Future proofing	5. *Fostering resilient healthy ecosystems is an imperative for policy and management.*
	6. *Policy and management must address spatial and temporal scales that match the values and issues of concern.*
	7. *Catchment management is essential for positive marine outcomes.*
	8. *In responding to threatening processes, it is essential to ensure ecosystem integrity.*
	9. *In protecting key species, site- and species-specific strategies are essential.*
Transformation and opportunity	10. *Changes brought about by a changing climate must be assessed for beneficial opportunities.*
	11. *In responding to increased climate variability and change, a transition towards flexible total stock or population management systems is essential.*
	12. *Policy and management must take advantage of the key role marine ecosystems can have in carbon sequestration.*
	13. *Carbon sequestration in marine systems is best done as part of a multi-objective approach.*

Revitalising Australia's Estuaries

Colin Creighton, Fisheries Research and Development Corporation

In the late 1990's scientists across Australia undertook an Australia-wide assessment of ~1,000 estuaries and embayments. This was part of the National Land and Water Resources Audit. Generally, the bigger the catchment and floodplain, the more degraded was the estuary and the more altered were the processes, flows and fluxes that characterise estuarine ecology. Urban, industrial and most importantly, agricultural development have been the fundamental causes of degradation of Australia's estuaries and embayments. This degradation has had major impacts on biodiversity, commercial and recreational fishing and indeed the Australian lifestyle. *Revitalising Australia's Estuaries* is a business case that builds on expertise and knowledge across Australia and provides an inventory of opportunities for repair, estimates the cost of repair and then through case studies demonstrates that an Australia wide investment of $350 million into estuarine rehabilitation will be returned in less than 5 years. This represents an outstanding return on investment, possibly far greater than most of Australia's previous environmental repair initiatives and with clear outcomes across the Australian food, lifestyle and services economies. Following a summary of *Revitalising Australia's Estuaries* this presentation will speculate on next steps and the necessary paradigm shifts in our thinking as scientists and managers if we are to once again have productive, healthy estuaries and embayments.

Revitalising Australia's Estuaries

- multiple benefits if we can meet the challenges of turning the tide on past mistakes

Estuaries & wetlands repair – key to productivity

Clarence River – 2013 Flood Event:

Everything dead - benthic sampling from Grafton [below tidal limit] to ocean [some 90 river km downstream at Yamba].

This image – de-oxygenation and acidic effluent from drained wetlands killed all worms generally found in sediments

Estuaries & wetlands repair

– key to Australia's productivity with multiple benefits

* Jobs
* Lifestyle
* Biodiversity
* Food security
* Balance of trade
* Health

But……how do we gain investment?

The state of play

1. For Australia's estuary dependent fisheries **our resource has markedly declined**

2. Many of us have already worked hard to protect fisheries habitat and to repair our estuaries - **much excellent work and research to build on**

3. However to make major gains in productivity we need **major leadership, strong partnerships & targeted investment**

4. To gain political and community support for major investment in estuary and fisheries habitat repair we need **clear and unambiguous benefits well exceeding the costs.**

The *Revitalising Australia's Estuaries* proposal:

❑ Planning works -	$21M	[6%]
❑ Works -	$238M	[68%]
❑ Monitoring -	$24.5M	[7%]
❑ Reporting-	$10.5M	[3%]
❑ Communication & Legacy	$17.5M	[5%]
❑ Policy development	$17.5M	[5%]
❑ Research& Knowledge	$21M	[6%]

Total of $350M with break-even on investment estimated at less than 5 years using just a selection of increased commercial catch rates.

Thematic Repair Priorities

* **Restoring connectivity and fish passage** – barrages, blocks, inadequate culverts, causeways
* **Restoring estuary processes** – especially tidal and freshwater flows and fluxes, ph and oxygenation
* **Repairing drained floodplain wetlands** – removing or manipulating barrages to allow tidal water and wetland recovery and reshaping landforms to remove drains and levees, especially for acid sulphate
* **Re-establishing mussel and oyster reefs** - key within-estuary nursery through to adult fishery habitat as well as performing a water quality improvement function
* **Re-establishing seagrasses** – replanting of initial re-colonizers especially in the SA gulfs and the provision of seagrass friendly moorings

South Australian Priorities

* **Coorong, Lower Lakes & Murray Mouth** – smarter barrage operations, re-connecting island creeks and overall aiming to increase the brackish zone
* **St Vincent and Spencer Gulfs**– seagrass re-establishment accompanied by continued investment to reduce catchment sourced deleterious water quality
* **Coastal Embayments and wetlands**– especially salt marshes and re-connecting tidal flows
* **South East Coastal Lakes- Lake Bonney SE and Lake George** – fish passage, connectivity and improved tidal flows

Productivity and the Value Proposition

- break-even analysis, justifying the benefits of major investment

Estuaries & wetlands repair – key to productivity

Summary Assumptions

A subset of regions - only selected regional fisheries analysed

A subset of species - only selected species within these regional fisheries and only using projected improved returns from commercial catch

$ Value as at 2013 retail value - $value used was 'at Retail' in 2013 to capture all the benefits along the value chain from fisher to processor and market to consumer.

All non-market benefits ignored – e.g. recreational & indigenous fishing, biodiversity, landscape amenity, flood management, lifestyle improvements, water quality, flood control, coastal buffering, carbon sequestration

Biological response only starts at the end of the investment period -fish populations do respond rapidly so there will be substantial ecological benefits before that time

Summary Assumptions [cont]

No improvements in technology of capture - methods of catch and aquaculture practices + entitlements and fisheries management arrangements assumed static

Demand to be totally elastic and the benefits of Australian product replacing imported product not included - domestic demand expands to take up all the additional seafood productivity. No account was taken of the improvements to Australia's balance of trade.

Market conditions as at 2013 - no increases in value factored in from such as consumer price index or for buyer preference for the fresher Australian product.

Catch share to broadly stay as for 2013 - the current partitioning of stock between wild-caught professional product, recreational catch and remaining uncaught wild population was estimated

A single regional fishery – the Coorong Murray mouth fishery

Selected commercial species - Mulloway, Yelloweye Mullet, Black Bream & Greenback Flounder

Estimated productivity value increases – set at 20%, or about $0.26M per annum increased value of product

Break-even point compared to estimated works cost – about 7 years

Multiple other benefits – e.g. Cockles, biomass such as Congoli, migratory waders and other World Heritage values, Ngarrindjeri culture

Improving the brackish mixing zone in southern Coorong is estimated to at least increase target commercial species by 20% annual sustainable catch

increased commercial landings will equal approximate cost of works in less than 7 years

A State - NSW & floodplain dominated estuaries

Selected commercial species - Sydney Rock Oysters, School Prawns and Mullet

Estimated productivity value increases –about $94M per annum increased value of product

Break-even point compared to estimated works cost – less than 3 years

Multiple other fish species benefits – e.g. Eastern King Prawn, Yellowfin Bream, Dusky Flathead, Luderick, Mulloway, Garfish, Eels and Whiting

+ water quality, flood control, waterfowl and beef grazing productivity


Floodgate and drain removal Clarence floodplain – **soil carbon + biodiversity + productivity + fishery + water quality**

Business as usual is drained poorly productive wetlands.....

An iconic region - Great Barrier Reef

Selected commercial species - Tiger and Banana Prawns

Estimated productivity value increases –about $45M per annum increased value of product

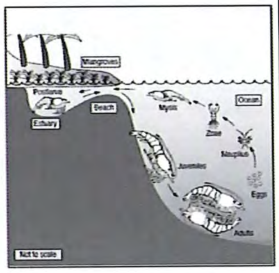
Break-even point compared to estimated works cost – less than 2 years

Multiple other fish species benefits – e.g. Barramundi, Mangrove jack, Estuary Cod, Red Emperor and flow on food chain benefits

+ Reef water quality, turtles and dugongs [seagrass improvements], tourism, indigenous culture and all related World Heritage values

Example – GBR, Tiger & Banana Prawns

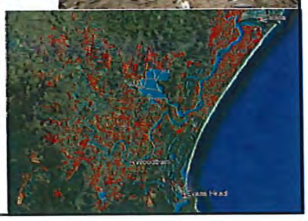
- reinstatement of salt marshes and related sandy, muddy and seagrass channels along the GBR coast would probably quadruple prawn catch

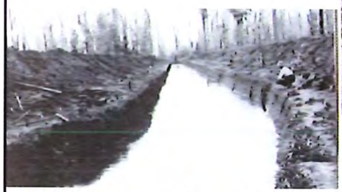


5 key messages

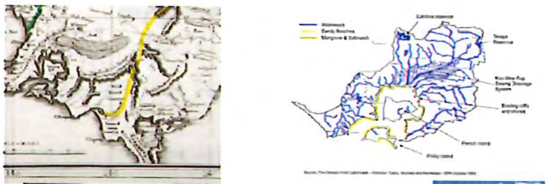
1. **Fisheries productivity** - our resource has markedly declined
2. **Change in our estuaries** – the next generation do not realise what is gone
3. **Understanding the repair opportunity** – our policy makers and advisors and community lack understanding of the opportunity
4. **Fisheries management** – time to understand the causes of productivity decline are NOT fishing
5. **Focus** – we need to capture the public's imagination with some clear sucesses


1 Fisheries Productivity e.g. - Richmond floodplain – massively drained for low value grazing

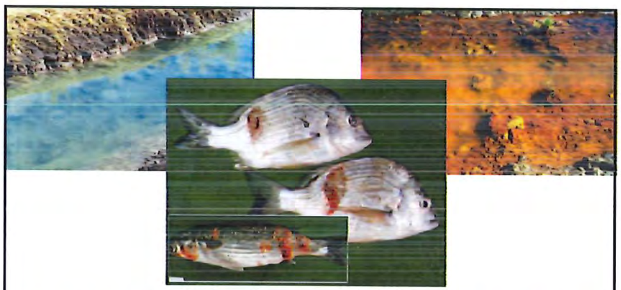




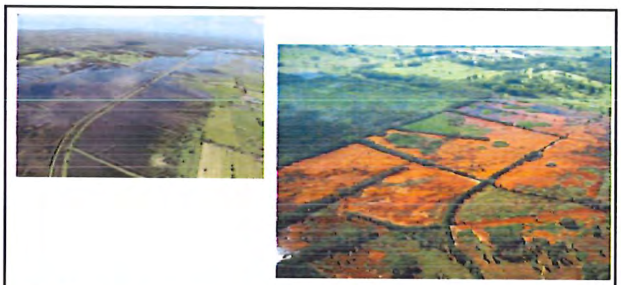

NSW – the basket case in wetland drainage and acidic deoxygenated effluent




2 Change - e.g.Westernport, Vic



- Repair the wetlands to minimize fish disease and oyster deaths



Big Swamp, Manning – pollution could be fish production

- Levees, drains, algae & de-oxygenation – how to start a "black water event", a fish and prawn kill .....OR ...trash the levee.

Acquisition + Repair - Everlasting Swamp & Sportman's Creek

- Tidal flow repair e.g. Shallow Channel, Clarence

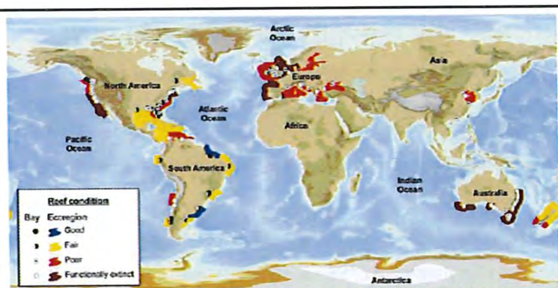
- 2 box culverts
- Green slime and mud to sand spits, high tidal flow and fast food zone

Shallow Channel, Clarence

Seagrass repair

Example: "crop circles" around moorings

Incentives for transition to seagrass friendly moorings and then regulate



Within Estuary Repair - If oyster and mussel reefs were the Great Barrier Reef...."functionally extinct"

Oyster and mussel reefs –

within estuary multi-dimensional habitat and purification systems

e.g. basis to re-establish Port Phillip snapper fishery

4 Fisheries Management

1. Over 70% of our commercial catch species have an estuary dependent phase – CPUE is not reflecting the main threats to our inshore fisheries; habitat loss, not effort is driving down population abundance

2. Probably 80% to 90% of recreational catch is estuary dependent – estuary fisheries provide for the Australian lifestyle...with over 3.4M Australians recreational fishers

3. Marine parks are less than optimum without fish! – time to also take an ecosystem approach to marine biodiversity conservation

4. Multiple other benefits – flood control, waterbirds, biodiversity, buffering, water quality, carbon sequestration

RESOURCE ALLOCATION – After we enhance productivity

Our policy & investment environment

Challenging....or perhaps its just "character building"!

* limited Aust. Govt. $ in environmental repair and many worthy opportunities
* likewise limited $ and many competing needs in States
* "infrastructure" is narrowly defined as "roads"
* food security seems to always forget the healthiest protein that does not need fertiliser or cultivation
* Australian fisheries painted negatively by simple messages on global fisheries
* as a community we readily eat imported catfish as the cheap seafood while neglecting the opportunities to re-establish such as *M. cephalus*

Our policy and investment environment [cont.]

There is a potential alignment of opportunities:

*$100M election commitment to RDCs that will be managed thru DAFF

* strong developing public – private partnerships [eg Fish Habitat Network, NGOs, US and UK examples]
* recognition that habitat repair is essential [e.g. recreational fisheries licence revenue re-investment programs in states]
* move towards "Trusts" starting with Great Barrier Reef
* capacity in agencies as demonstrated by National Estuary Network
* capacity and strong interest in the R&D community

5. Focus – my thoughts for where to now...

My suggested criteria for a set of key projects for a phase 1 -

1. Each project is <u>large in scale and vision</u> to capture public support and media attention......and MUST be achievable
2. Need <u>multi-partners</u> across public and private sectors - contributing $ and commitment
3. Projects should lead to major productivity improvements in an iconic fishery / enhanced biodiversity / community lifestyle
4. Must have <u>high</u> likelihood of success and <u>low</u> risk
5. Must be coupled with R&D and monitor change to demonstrate success.

The very draft suggestion

A "Phase I" Strategic Package across R&D + Works could be -

* GBR – ponded pastures
* SEQ – seagrass friendly moorings
* NSW – floodplain repair [Clarence and Richmond]
* Vic – Port Phillip oyster / mussel reefs
* Tas – D'Encastreaux oyster / mussel reefs
* SA – Gulf seagrasses and Lake Boney SE
* WA – Vasse – Wonnerup system repair
* NT – protection policy, suggested legislation and offset protocols

In brief:

* **<u>Focus</u> to demonstrate the vision**
* **<u>Align</u> R&D and Works to ensure success**
* **<u>Monitor</u> to demonstrate ROI**
* **<u>Collaborate</u> as exemplar public-private partnerships**
* **<u>Promote</u> to position for phase II $ investment.**

Estuaries & wetlands repair – key to productivity

Rethinking fisheries management as a combined response to changing climate, habitat & fishing pressure

Colin Creighton, Chair, Climate Change Adaptation – Marine Biodiversity & Fisheries, FRDC

Under classic fisheries management theory fisheries typically move from "nascent" to "developed" and then to a "sustainably developed" phase with maximum sustainable yield as the goal of management. This classic theory looks principally at fishing pressure. A more recent trend in fisheries management is towards "economically sustainable yield" or maximum economic yield. In tracking progress towards managed sustainability the most commonly used metric is a measure of catch per unit effort [CPUE]. Fisheries managers regard stable CPUE as evidence of "sustainable" fishing. However, for many coastal / nearshore target species, and indeed about 75% of Australia's commercial catch with its estuary dependent lifecycle, fishing effort and catch may not be the major stressor. Loss of habitat, covering both physical habitat loss and declining water quality can be the major stressor on total population size. The other major influence that must be taken into account is Australia's variable and changing climate. This presentation draws heavily on the findings of multiple completed research projects undertaken as part of the FRDC – DCCEE Climate Change Adaptation Initiative and speculates on how we might need to reform our fisheries management systems. The presentation concludes with a suite of criteria for smarter fisheries management that by being centred on stock productivity can incorporate the issues of resource allocation, habitat condition and climate variability / change.

Rethinking fisheries management

- responding to a changing climate, habitat loss & community pressures

Colin Creighton + many contributors

Identification of climate-driven species shifts and adaptation options for recreational fishers

Climate Adaptation

www.csiro.au

Daniel Gledhill,
16 February, 2012

National Research FLAGSHIPS Climate Adaptation

CSIRO

Beach and Surf Tourism and Recreation in Australia: Vulnerability and Adaptation (BASTRA)

PI: A/Prof Mike Raybould
Dave Anning (Bond University)
Dan Ware (Griffith University
Neil Lazarow (Advisory-DCCEE)

NCCARF National Climate Change Adaptation Research Facility

BOND UNIVERSITY

Griffith UNIVERSITY

Australian Government Fisheries Research and Development Corporation

Management implications of climate change impacts on fisheries resources of tropical Australia

David Welch, Julie Robins, Thor Saunders, Andrew Tobin, Colin Simpfendorfer, Johanna Johnson, Gretta Pecl, Jeff Maynard, Steve Matthews, Mark Lightowler, Bill Sawynok, Randall Owens, Eric Perez

JCU, C2O Fisheries, Qld DEEDI, NT DoR, GBRMPA, QSIA, Infofish Australia, UTAS, C2O Consulting, Maynard Marine

FRDC-DCCEE Project: 2010/535
Management implications of climate change effects on fisheries in WA

Nick Caputi

16 February 2012

western australian marine science institution

Australian Government Fisheries Research and Development Corporation

National Research FLAGSHIPS Wealth from Oceans

CSIRO

Department of Fisheries Government of Western Australia

A climate change adaptation blueprint for coastal regional communities

Stewart Frusher	(IMAS - Hobart)
Nadine Marshall	(CSIRO – Townsville)
Malcolm Tull	(Murdoch Uni - Perth)
Sarah Metcalf	(Murdoch Uni - Perth)
Ingrid van Putten	(IMAS and CSIRO - Hobart)

UTAS

Murdoch UNIVERSITY

IMAS

CSIRO

Australian Government Department of Climate Change and Energy Efficiency Fisheries Research and Development Corporation

western australian marine science institution

INSTITUTE FOR MARINE AND ANTARCTIC STUDIES

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www.imas.utas.edu.au

Preparing fisheries for climate change: identifying adaptation options for four key fisheries in SE Australia

Team: Gretta Pecl & Tim Ward (co-PI's)
Dallas D'Silva, Caleb Gardner, Philip Gibbs, Andrew Goulstone, Alistair Hobday, Greg Jenkins, Stephen Mayfield & many others

Victoria Department of Primary Industries · NSW Industry & Investment · National Research FLAGSHIPS · CSIRO · Australian Government Department of Agriculture, Fisheries and Forestry · Government of South Australia · SARDI · UTAS · Tasmania Explore the possibilities

IMAS - in partnership with the Tasmanian State Government

Aquaculture Genetics James Cook University · JAMES COOK UNIVERSITY AUSTRALIA

Vulnerability of barramundi and related industries to climate change

Dean Jerry, Carolyn Smith-Keune, Guy Carton, Jeremy vanderWal, Igor Pirozzi, Kate Hutson and John Russell (QDEEDI)

James Cook University
Townsville, QLD
Australia

Changing Currents in Marine Biodiversity Governance and Management: Responding to Climate Change

Michael Lockwood[a]
Julie Davidson[a]
Marc Hockings[b]
Marcus Haward[c]
Lorne Kriwoken[a]

[a]Geography and Environmental Studies, University of Tasmania
[b]Geography, Planning & Env. Management, University of Queensland
[c]School of Government, University of Tasmania

Assessing Alternative Adaptive Management Strategies for Estuarine and Coastal Ecosystems

Marcus Sheaves JCU
Rodrigo Bustamante CSIRO
Cathy Dichmont CSIRO
Jeremy Hindell DSE
Marie Savina-Rolland CSIRO
Pat Dale GU
Nina McLean JCU

JAMES COOK UNIVERSITY AUSTRALIA · CSIRO · Victoria · Griffith University

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Effects of climate change on coral trout (*Plectropomus leopardus*)

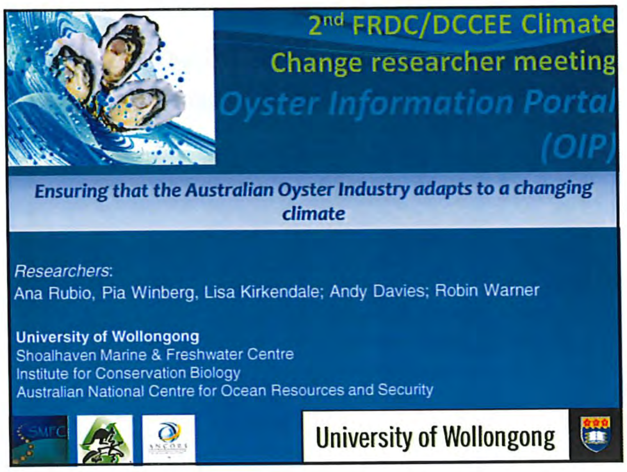
Morgan Pratchett, Philip Munday, Vanessa Messmer
James Cook University, Townsville

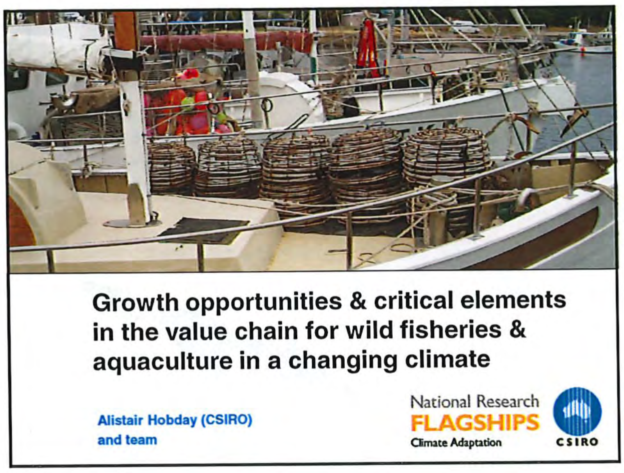
Richard Knuckey, Adam Reynolds
QDEEDI Northern Fisheries Centre, Cairns

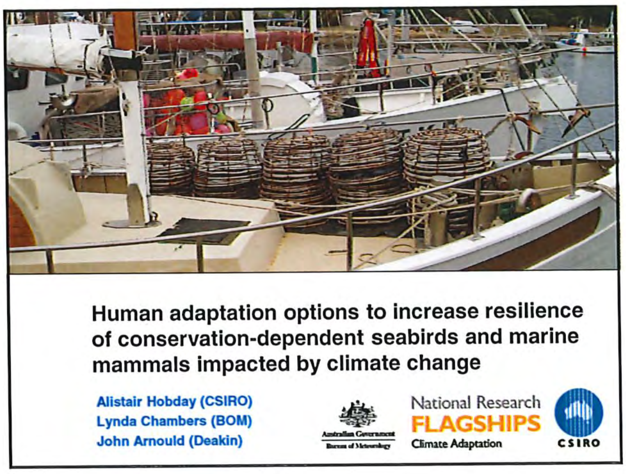
Adaptive Management of Temperate Reefs for Climate Change: New approaches for ecological monitoring and predictive modelling

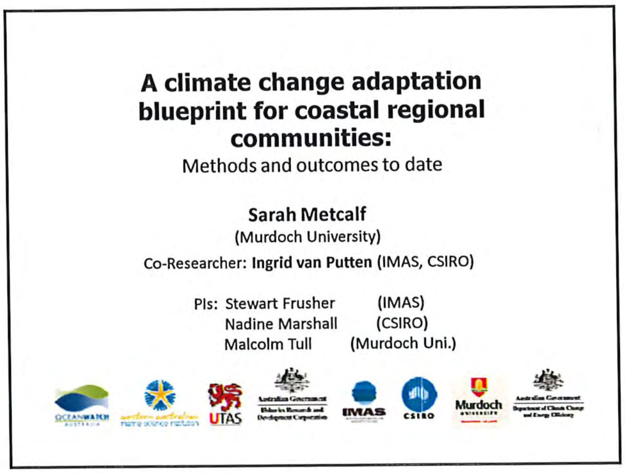
Neville Barrett, Graham Edgar, Neil Holbrook and others

UTAS

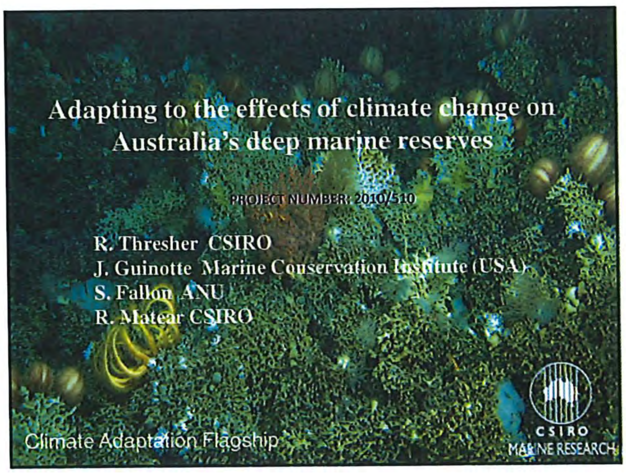

2nd FRDC/DCCEE Climate Change researcher meeting
Oyster Information Portal (OIP)
Ensuring that the Australian Oyster Industry adapts to a changing climate
Researchers:
Ana Rubio, Pia Winberg, Lisa Kirkendale; Andy Davies; Robin Warner
University of Wollongong
Shoalhaven Marine & Freshwater Centre
Institute for Conservation Biology
Australian National Centre for Ocean Resources and Security
University of Wollongong


Growth opportunities & critical elements in the value chain for wild fisheries & aquaculture in a changing climate
Alistair Hobday (CSIRO)
and team
National Research
FLAGSHIPS
Climate Adaptation
CSIRO


Human adaptation options to increase resilience of conservation-dependent seabirds and marine mammals impacted by climate change
Alistair Hobday (CSIRO)
Lynda Chambers (BOM)
John Arnould (Deakin)
Australian Government
Bureau of Meteorology
National Research
FLAGSHIPS
Climate Adaptation
CSIRO


A climate change adaptation blueprint for coastal regional communities:
Methods and outcomes to date
Sarah Metcalf
(Murdoch University)
Co-Researcher: Ingrid van Putten (IMAS, CSIRO)
PIs: Stewart Frusher (IMAS)
Nadine Marshall (CSIRO)
Malcolm Tull (Murdoch Uni.)
UTAS
IMAS
CSIRO
Murdoch


Climate Change Adaptation
Building Community and Industry Knowledge
FRDC 2011/503
Jenny Shaw
western australian marine science institution
Australian Government
Fisheries Research and Development Corporation
OCEANWATCH AUSTRALIA
UTAS
Murdoch
Curtin University
CSIRO
WIN


Adapting to the effects of climate change on Australia's deep marine reserves
PROJECT NUMBER: 2010/510
R. Thresher CSIRO
J. Guinotte Marine Conservation Institute (USA)
S. Fallon ANU
R. Matear CSIRO
Climate Adaptation Flagship
CSIRO
MARINE RESEARCH

FRDC-DCCEE: preparing fisheries for climate change: identifying adaptation options for four key fisheries in South Eastern Australia, 2011/039

PRINCIPAL INVESTIGATORS: **Gretta Pecl and Tim Ward**

Final report due January 10th **2014**

Imperatives for marine biodiversity & fisheries management

Key descriptors for successful management -
- dynamic, changing, flexible, adaptive, resilient, integrative and responsive

Status -
- reactive policy, value laden, limited evidence, inherently refractory decision making, simple [and often incorrect] messages, inadequate understanding

A 5-part suite of management criteria

A – incorporating climate in our thinking

B – accommodating shocks and variability

C – responding proactively

D – re-building productivity and profitability

E – contributing to a smart carbon economy

A suite of management criteria
[A -incorporating climate in our thinking]

1. **Climate adaptation** – a part of much larger social and economic adaptation [e.g. changing input costs / technology / commodity prices & markets]
2. **Climate** – part of integrative, more multi-objective policy & management [within sustainable economic yield & conservation policies]
3. **Management approaches** – developing policies that match in coverage [spatially and temporally] what we seek to manage [more holistic / regional approaches e.g. snapper; eastern and southern rock lobster; abalone]

A suite of management criteria
[B - accommodating shocks and variability]

4. **Minimising the impact of extreme events** – an imperative for fostering resilient, healthy ecosystems [e.g. cyclone impacts on coral trout fishery; western rock & abalone – Leewin current;]
5. **Catchment management** – essential for fisheries outcomes [e.g. fish kills with floods; Shark Bay prawn and scallop]
6. **Responding to variability** – towards flexible total stock management [e.g. barramundi @ 3 years; prawns annually;]

A suite of management criteria
[C - responding proactively]

7. **Responding to changing interactions** – including climate influences in any assessments [eddies and fish concentrations, Eastern Australian Current; recreational fishing target effort]
8. **Responding to threatening processes** – to ensure ecosystem integrity [e.g. static marine park boundaries; water quality and habitat loss]
9. **Responding to non-static conditions** – policy, procedures and regulations must be as flexible as the variability of the stocks and ecosystems we seek to manage [e.g. Eastern Blue Groper; sea urchin – kelp - Southern Rock Lobster interactions;]

A suite of management criteria
[D - re-building productivity and profitability]

10. **Repairing for increased resilience** – a priority for investment [especially inshore habitat]
11. **Protecting key species** – site and species specific investment will be essential [e.g. seabirds marine mammals]
12. **Changing climate** – a profitability opportunity [e.g. Eastern Rock Lobster; Barramundi aquaculture; concentrations on eddies; mussel and oyster reefs as 3D natural habitat]

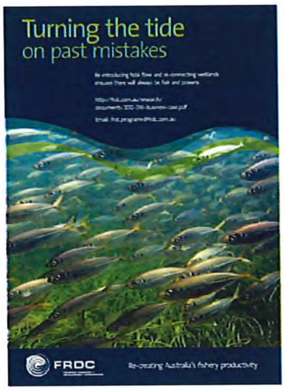
And the dark (or at least black) side!
[E - contributing to a smart carbon economy]

13. **Marine ecosystems** – a key role in carbon sequestration (and Australia's regional development!) [mangroves, seagrasses, fresh to brackish wetlands and salt marshes are the highest per hectare carbon sequesters]
14. **Smarter fuel & energy use** – essential for profitability [e.g. fuel management, gear technology]

Revitalising Australia's Estuaries

- **multiple benefits if we can meet the challenges of turning the tide on past mistakes**

(See special session organised by Paul Hamer on Thursday afternoon)



Estuaries & wetlands repair – key to productivity

R&D Priorities - Australia's estuaries, embayments and nearshore marine environments

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Abstract / Summary
Southern Australia's estuaries and inshore waters are the most degraded of all Australia's ecosystems. Yet naturally, estuaries and inshore waters are globally the most productive and in Australia's case, with its narrow continental shelf, are much of the basis of our fisheries and biodiversity. These sheltered water support critical life cycle components of the majority of our recreational and professional fishing target species and are a key component of our Australian lifestyle. As already well demonstrated in USA, UK and the EU transitional waters initiatives, repair of past damage to foster recovery of productivity within these key ecosystems is now a very attractive investment. Flow on benefits will be substantial - ecologically, economically and socially with outcomes of healthy high quality seafood, enhanced urban & coastal lifestyle, re-established habitat for rare & endangered fish, birds & vegetation, world heritage area repair, improved flood management and increased regional employment. This paper therefore focuses on the R&D required to underpin the repair and ongoing management of these high value ecosystems for both improved productivity and enhanced conservation values.

1. Background

Broad Management-Orientated Definition - In this paper we adopt a broad definition of the term 'estuary', orientated towards human use and management: estuaries are defined as all semi-enclosed coastal waterbodies where marine water from the ocean mixed with freshwater draining from the land, and/or any coastal environment where marine and fluvial sediments occurred together (e.g. National Land and Water Resources Audit 2002). This management-orientated definition is much broader than the long-standing and widely accepted biophysical definition of an estuary as 'a body of water in which river water mixes with and measurably dilutes sea water' (e.g. Reid 1961,Hodgkin 1994).

Continuing Degradation of Ecosystems and Productivity –There is an ongoing trend of degradation of Australia's inshore and nearshore ecosystems and the loss of fish habitat, of seagrass-beds, mangroves, saltmarshes and fresh to brackish sedge and paperbark floodplain wetlands. In turn, this loss of habitat is associated with changes in fisheries catches and there is now abundant evidence that Australia is progressively losing commercial and recreational fisheries on a nation-wide scale. Fisheries resources are important for high value secure food supply, for the commercial, recreational and indigenous fishing sectors, and also have ramifications from lifestyle and tourism perspectives (e.g. Smith 1981; Creighton 1982; Skilleter and Loneragan 2007).

Excessive Nutrients, Algae and Hypoxia - Micro-tidal systems are particularly prone to extreme eutrophication and thus hypoxia, which is clearly a major problem in many estuaries in southern Australia with their limited tidal range and often alterations to tidal flow that has accompanied development (e.g. Diaz 2002; Vaquer-Sunyer and Duarte 2008). This is of particular relevance for the two Gulfs and other inverse estuaries in South Australia. According to Diaz (2002) "no other environmental variable of such ecological importance to estuarine and coastal ecosystems around the world has changed so dramatically, in such a short period of time, as dissolved oxygen". Furthermore, Diaz points out that this threatens the "loss of fisheries and biodiversity and alteration of food webs in these systems".

Reduced fisheries productivity - Over 75 % of Australia's commercial fish catch, and in some regions up to 90% of all recreational angling catch, spends part of its life cycle within estuaries and inshore wetlands (Copeland and Pollard 1996; Lloyd 1996; Bryars *et al.* 2003; New South Wales Department of Primary Industries 2007, 2008; Jerry 2013). Total populations of many inshore fisheries species have declined (e.g. Creighton 1982), and, should habitat continue to be lost, it is almost inevitable that fish populations will continue to decline. Major fish kills in estuaries, often associated with the drainage of floodplain wetlands, the activation of acid sulfate soils, and alterations to freshwater flows, have been frequent events in New South Wales, e.g. Clarence and Richmond River systems in 2009, 2010, 2011, and 2013 (Ryder and Mika 2013; see also White *et al.* 1997; Wilson *et al.* 1999; Johnston *et al.* 2003a).

Example - Prawn and scale-fish fisheries, New South Wales - The School Prawn *Metapenaeus macleayi* is an annual, highly fecund stock that, if habitat is present, provides a resilient and highly productive commercial and recreational fishery. Yet, in estuaries such as the Shoalhaven River, both the commercial and recreational fisheries have been lost since the early 1980's due to deteriorating estuarine condition. Similar comments apply to the Western School Prawn *Metapenaeus dalli* and the reduced productivity in the estuaries of south-western Western Australia (Potter *et al.* 1986, 1989; Smith *et al.* 2007).

In New South Wales, School Prawn and Eastern King Prawn *Penaeus plebejus* fisheries are considered fully exploited and overfished, respectively (NSW Industry and Investment 2010; Rowling *et al* 2010). Catch rates are now at most ~75% of those catch rates that were maintained historically during the 1970s and 1980s, and some rivers only support recreational prawn catches (New South Wales Industry and Investment 2010). The Estuarine General Fishery in New South Wales has never surpassed the levels of production of the 1960s and 1970s. For commercially valuable fisheries, such as Dusky Flathead *Platcephalus fuscus*, Sea Mullet *Mugil cephalus*, Sand Whiting *Sillaginodes punctatus* and *Sillago ciliate*, Luderick *Girella tricuspidata*, Mulloway *Argyrosomus japonicus*, and Yellowfin Bream *Acanthopagrus australis*, average catches have declined markedly from those that were maintained in the 1960s and 1970s (New South Wales Industry and Investment 2010; Silberschneider and Gray 2008).

Part of the decline in these fisheries could be due to improvements in the rigour of fisheries management to ensure sustainability, as well as resource sharing as the recreational sector has increased in effort. Part could be due also to profitability issues, such as increasing input costs of diesel and labour or price competition from imported products. Part could also be due to loss of resilience due to a combination of environmental degradation and the impacts of fishing. For example, loss of egg production capacity as large females are removed by fishing, thus reduced opportunity to respond to infrequent favourable conditions for breeding. Nevertheless, the broad and consistent trends for most species in wild fisheries along the New South Wales coast indicate that the underlying factors of water quality and habitat loss predominate. Specifically, the reductions in total populations are likely to be due firstly to limitations to recruitment, growth and productivity due to loss of habitat and changes in tidal and freshwater flow regimes; secondly, massive water quality induced kills are likely to have had an impact on total biomass, the almost total loss of some species (e.g. Sydney Rock Oysters and Mud Oysters *Ostrea angasi* from many NSW floodplain estuaries) and possibly overall species composition of estuary fish populations. Much of the water-quality decline, especially in changed pH, pollutants such as heavy metals, and anoxic or low dissolved-oxygen conditions are due to the draining of the critical estuarine habitats, the floodplain wetlands, salt marshes and accompanying seagrass-lined channels (Wood 2007; Government of South Australia 2009, 2012; Grabowski and Peterson 2007).

To put it bluntly – when indicators such as the highly fecund annual stocks such as prawns are in decline and when what must be regarded as Australia's "native inshore carp", the highly fecund algae-feeding *Mugil cephalus* are also in decline its time for R&D to focus on how best to repair the overall productivity of Australia's estuaries, embayments and nearshore marine environments.

2. Opportunities for repair– what needs to be done

Comprehensive work undertaken by Creighton in consultation with relevant stakeholders, has identified five relatively discrete repair themes (Creighton, 2013):

i) restoring longitudinal and lateral connectivity to ensure fish passage and nutrient flux (Sheaves *et al.* 2014). This will involve removal of barrages, inadequate culverts and causeways and other blockages to the movement of animals and plants, their propagules, tidal and freshwater flows, and the flux of nutrients;

ii) rehabilitating degraded floodplain wetlands, which can be achieved in part via removing or manipulating barrages to allow more natural fluxes of water, and reshaping landforms to remove drains and levees. Acid sulfate soil will require particular attention (Boys et al 2012, Cook *et al.* 2000);

iii) re-establishing native mussel and oyster reefs, which provide valuable habitat and nursery areas for many estuarine fish species, as well as performing valuable water-quality improvement functions;

iv) protecting and, if required, re-establishing seagrass beds. The provision of seagrass-friendly moorings in areas subject to heavy recreational boating is likely to be an important component of this action; and

v) acknowledging the defining characteristic of estuaries – that they are the meeting place of fresh waters and marine waters –by maintaining both adequate freshwater flows to the lower reaches of coastal floodplain rivers (Gillanders and Kingsford 2002) and tidal flows from the ocean.

3. Research Priorities

3.1 Theme - Ecosystem ecology and responses

Event management for landscape optimization

Undertake multi-objective analysis of selected flood-prone systems, such as southern Queensland (e.g. Mary River) and a northern New South Wales river (e.g. Richmond or

Clarence), to understand how best to optimize floodplain management across multiple land uses and objectives. For this study, good hydrographic models are needed as a base. The research would establish how best to utilize wetlands, levees, dredging, flood infrastructure, roading, flood storage and so on for the multiple objectives of fisheries, biodiversity, water quality, urban and infrastructure flood protection and agriculture.
Output – *Multi-criteria analysis method for optimizing outcomes for the landscape to deliver both human use/ economic and ecological benefits.*

Tidal hydrology and repair of morphology
Sedimentation from catchment loads and infrastructure such as training walls, crossings and causeways has changed tidal hydrodynamics and therefore net primary productivity. Repair dredging (e.g. Manning entrance plus many within-estuary sites), alterations to historic training walls (e.g. Middle Wall, Clarence; Googleys Lagoon, Camden Haven) and alterations to causeways and current sedimentation patterns (e.g. Clarence – Shallow Channel, Romiaka Channel, Oyster Channel and Palmers Channel feeding Lake Wooloweyah) may all be useful repair techniques. When considering improved tidal ventilation, it will also be essential to incorporate the flow on benefits of how such works could improve wetland productivity and contribute to repaired habitat as part of initiatives such as seagrass re-establishment.
Output – *designed guidelines for repair of selected estuaries that also provide a model for application in other inshore waterways.*

What is the likely total population of key species, how does population vary with climate and how should this be used to improve fisheries management, including resource sharing?
Whilst recreational effort is increasing in inshore / nearshore, particularly around major urban centers, variable climate impact in fish and crustacean population fluctuations. If the variation in populations and the drivers for these variations are documented, a suite of likely carrying capacities can also be projected. This could form the basis for the impacts of any major development and any major repair activities, which may lead to better development and investment decisions. The flow-on of linking professional fishing effort to stock availability and any resource sharing rules would also make commercial fisheries more profitable and sustainable in the long term.
Output – *changed paradigms for fishing effort management, resource sharing and development approvals by considering cumulative impacts based on a carrying capacity approach.*

Developing accurate assessments of the standing stocks, stock dynamics and specific productivity and value of particular estuaries, estuary reaches or estuary sub-habitats.
Effective repair and revitalization of estuary function depends on being able to identify the specific values of different assets (whole estuaries, estuary reaches, sub-habitats [e.g. transitional or seasonal wetlands, seagrass beds mangrove banks]). This relies on accurate information on productivity and productivity dynamics (e.g. accurately understanding the distribution and dynamics of fisheries species biomass). However, this information is rarely available for any estuary or estuary component, despite the fact that this is also key information needed to support decisions on development, determining offsets, etc.
Output – *increased ability to efficiently and cost effectively direct repair, remediation, offsets and development decisions to provide the optimal fisheries outcomes.*

Priority locations – do they exist for Australian inshore species?
New Zealand research suggests some species may have priority location nursery habitats forup to 80% of their stock in a particular estuary, later dispersing widely. Does this occur in Australia (possibly Murray/ King George Whiting in Spencer Gulf)? For example, Murray River estuary

and Coorong lagoons provide priority habitat for *A. japonicas* (Ferguson et al, 2008). Nursery areas for snapper are likely to include upper parts of the SA Gulfs and probably were the shellfish reefs of sheltered embayments such as Port Phillip and Moreton Bay. (e.g. Fowler et al 2003). If so, how would we best protect / manage these extra important areas?
Output – *better understanding of locational preferences as a basis for improved ecosystem and population management.*

The freshwater–brackish–saline interface and net primary productivity
Brackish, intermixed systems are globally the most productive ecosystems. How can we change catchment hydrographs and inshore hydrodynamics back towards a more sinusoidal long recession curve-mixing system that facilitates large brackish areas inshore?
Output – *Better understanding of catchment hydrology linked to net primary productivity, especially important for more regulated estuary systems.*

Larval recruitment – has it been influenced by training walls and other structures that impact on tidal flows?
Major wave-dominated estuaries pre-settlement were a maze of entrance sand spits. Much of the spawning (Mullet, Bream, Whiting, Mulloway) presumably occurred in those estuaries with a high probability of rapid larval recruitment back into the sheltered waters. Where do these species spawn now and can any manipulation of estuarine entrance areas assist higher recruitment back into estuaries? A further likely impact of changed hydrodynamics is disrupted cues to assist larvae in locating high quality nursery habitat.
Output – *Better understanding of larval dispersal and opportunities to enhance recruitment to nursery areas.*

3.2 Theme - Human interactions with ecosystems

Mixing the public and private benefits of waterway and wetland conservation – should fishers pay farmers and other land users?
Much of the challenge with waterway / nearshore management lies in the public benefits that these assets provide compared to the private benefits that come from land development. On Australia's floodplains and coastal catchments, development has been for private benefit, especially agriculture and grazing with now increasingly urban development, at the expense of the more public benefits of biodiversity, water quality and fisheries. Fisheries can also lead to private benefit when professionally harvested for food or caught as part of recreation and lifestyle. How can these various benefit streams be brought together to ensure ongoing investment in ecosystem repair and management for benefit of all?
Output – *Exploration of the opportunities for cross-subsidization between public and private beneficiaries; better understanding of the externalities to our economic systems.*

Sustainable fisheries management – should this be based on habitat condition and the habitat's potential for productivity?
Historically fisheries management has been preoccupied with management of single species through input controls such as fishing gear, size of boat, temporal closures etc. Fisheries management is gradually moving towards output controls based on the presumed, sometimes modeled and monitored, size of the population available for catch and therefore some estimate of 'sustainable yield'. However, with well over 70% of all professional catch Australia-wide having an estuary-dependent phase in their lifecycle, these estimates of sustainable yield should also be taking into account factors affecting the whole ecosystem rather than species level only. Although ecosystem-based fisheries management practices have progressed understanding of fishing impacts at an ecosystem level, more has to be done. For example, habitat condition, improvement or decline, provides a basic level upon which, through repair, sustainable yield can

be increased, or, as is currently the case, do nothing so that sustainable yield will continue to decline regardless of what controls are placed on effort.
Output – *Linking habitat condition to sustainable yield should give further impetus to better management of inshore and nearshore habitats, or, at least, foster understanding that further degradation has a direct impact on seafood security, jobs and recreational lifestyle.*

Fostering local stewardship – what works?
Recreational fishers have a lead role in estuary and nearshore management, repair and protection in both the UK and USA. Australia has over 3.4 million recreational fishers. Galvanizing this sector of the population to a lead role in management, repair and protection will reduce the need for ongoing government investment as greater stewardship is developed.
Output – *Schemes and engagement models in place overseas and in some states could be explored to provide a kitbag of possible schemes for Australia for the various recreational fisher groups to consider.*

Understanding and valuing the multiple outcomes that accrue from good management
Multiple benefits besides fishery productivity accrue from good management. These include flood control, coastal biodiversity, extreme climate event buffering, good water quality, scenic landscape and general public amenity, and carbon mitigation. Most of these are public benefits. Understanding these benefits and their overall value can influence public investment and community behaviour.
Output – *A better understanding of the role and benefits of improved management.*

Evaluation and reporting of effectiveness of policy, legislation and regulations – what works?
Various states have differing levels of environmental policy and legal frameworks pertaining to the management of inshore waters, estuaries, nearshore and wetlands. The effectiveness of these instruments is rarely evaluated. Evaluation and reporting are fundamental to generating continuous improvement, which leads to greater efficient, effective and appropriate use and management of resources. this paper focuses on repair attests to their aggregate failure in maintaining productivity for the Australian public good and seafood food security.
Output – *An evaluation of the various approaches to policy, legislation and regulations, and the development of model provisions may be the first step towards improved policy and regulatory frameworks in all jurisdictions.*

Resource sharing within repaired inshore and nearshore environments
By virtue of their location and being the more sheltered easily accessible waters, estuaries, embayments and nearshore marine environments are generally areas of high recreational effort. Professional catch also has a high inshore dependence. Rebuilding habitats such as mussel or oyster reefs in Port Phillip or Moreton Bay is likely to lead to increased recreational pressure. How can any increases in productivity be best shared? If recreational fishing was to fully fund a mussel reef, then should all the benefits accrue to recreational fishing? Is this a vehicle whereby increased private sector investment in repair could be encouraged?
Output – *Exploration of the various options for resource sharing and how it might link to investment in repair.*

4. Realisation

Infrastructure perspective – existing science infrastructure is sufficient for the suite of science. While many state agencies have recently reduced available laboratory and vessel infrastructure, all states still maintain sufficient infrastructure for their purposes in universities and agencies. Better coordination of projects and programs would allow for greater sharing and more efficient use of existing infrastructure.

Science Capability – much of the capability previously residing within state agencies is now with leading universities and research organizations. There are groups and teams of highly competent scientists in all states – eg Murdoch, WAMSI and Curtin in WA; SARDI and Univ. of Adelaide in SA; UTAS and CSIRO in Tasmania; DPI Vic, Melbourne and Victoria Univ. in Victoria; NSW Fisheries Univ. of Wollongong, NSW Univ. Hydrology Lab and Sydney Univ. Marine Institute in NSW; JCU, AIMS and CSIRO in Qld. For Northern Australia, the priorities are more around protective management and policy development than repair. Science capability resides in Charles Darwin Univ., AIMS and agencies for these purposes.

Co-investment in Repair Works–All the R&D priorities proposed will be best done using Australian coasts, estuaries and inshore environments as a "living laboratory". Creighton, 2013 outlines a proposed investment package of $350M which includes first order works, R&D, monitoring, evaluation and communication. In light of budgetary limitations, this level of Australian Govt. investment may be achieved through a series of individual investments. In progress so far from the works perspective is:

- $40M initially allocated under Reef Rescue II towards "system repair"....but only a proportion of this is contracted and not all projects focus on estuary and wetland systems;
- $300K from the US Nature Conservancy to foster a trial of shellfish beds in Port Phillip; and
- several existing and some planned acquisitions of key wetlands and their repair in NSW – via NSW Fisheries and National Parks Service.

Many State governments, including SA, Vic, NSW and QLD already reallocate revenue collected from recreational fishing licences / boat registrations to improving recreational experiences. As the various community groups recognise, the key part of the experience needing investment is re-establishing healthy and bio-diverse ecosystems. Several states are likely to offer to partner with a R&D initiative that focuses on repair. For example, South Australia has been working on seagrass restoration and rehabilitation for many years.

Coordination – Strong and strategic coordination is essential for this initiative to be successful. In fact, part of the reason for the demise of these otherwise highly productive ecosystems is the limited integration and coordination, to date, in catchment use / floodplain management / coastal development. There are multiple players and multiple benefits derived from these landscapes. Cohesive and collaborative R&D focused on key issues and well linked to repair works will be essential if Australia is to derive maximum benefit from R&D investment.

Funding–Potential sources of funding, preferably well coordinated and focused, could include:

- National Environmental Science Program;
- FRDC and possibly a component of the $100M election commitment to RDCs for enhanced primary industry productivity;
- State Govts. with their various recreational fishing and boating licence reallocation systems; and
- Private sector and NGOs as already demonstrated by the US Nature Conservancy.

5. Conclusions

Much has been learnt scientifically regarding the impacts of our land practices and water allocation decisions on Australia's estuaries, embayments and nearshore marine environment. Science has provided greater understanding of the consequences due to changes to water quality and sediment load, the mobilisation of salts by dryland salinity, the loss of biodiversity, the reduction of fisheries productivity and others. The ongoing need for scientific understanding of these issues is greatly acknowledge through existing funding allocation mechanisms.

It is now timely for R&D to focus on repairing Australia's most degraded ecosystems and the multiple economic and environmental services they provide so that we can add the concepts of estuarine repair and land use optimisation to the toolkits of enhanced food security, primary industry development and environmental repair.

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Revitalising Australia's Estuaries

- multiple benefits if we can meet the challenges of turning the tide on past mistakes

Estuaries & wetlands repair – key to productivity

Clarence River – 2013 Flood Event:

Everything dead - benthic sampling from Grafton [below tidal limit] to ocean [some 90 river km downstream at Yamba].

This image – de-oxygenation and acidic effluent from drained wetlands killed all worms generally found in sediments

Estuaries & wetlands repair

– key to Australia's productivity with multiple benefits

* Jobs
* Lifestyle
* Biodiversity
* Food security
* Balance of trade
* Health

But……how do we gain investment?

5 key messages

1. **Fisheries productivity** - our resource has markedly declined
2. **Change in our estuaries** – the next generation do not realise what is gone
3. **Understanding the repair opportunity** – our policy makers and advisors and community lack understanding of the opportunity
4. **Fisheries management** – time to understand the causes of productivity decline are NOT fishing
5. **Focus** – we need to capture the public's imagination with some clear sucesses

1 Fisheries Productivity e.g. - Richmond floodplain – massively drained for low value grazing

3 Opportunities - thematic repair priorities

* **Restoring connectivity and fish passage** – barrages, blocks, inadequate culverts, causeways
* **Restoring estuary processes** – especially tidal and freshwater flows and fluxes, ph and oxygenation
* **Repairing drained floodplain wetlands** – removing or manipulating barrages to allow tidal water and wetland recovery and reshaping landforms to remove drains and levees, especially for acid sulphate
* **Re-establishing mussel and oyster reefs** - key within-estuary nursery through to adult fishery habitat as well as performing a water quality improvement function
* **Re-establishing seagrasses** – replanting of initial re-colonizers especially in the SA gulfs and the provision of seagrass friendly moorings

4 Fisheries Management

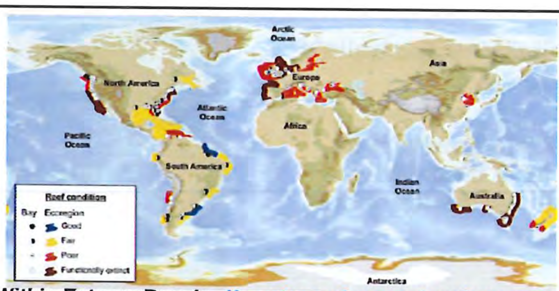
1. Over 70% of our commercial catch species have an estuary dependent phase – CPUE is not reflecting the main threats to our inshore fisheries; habitat loss, not effort is driving down population abundance

2. Probably 80% to 90% of recreational catch is estuary dependent – estuary fisheries provide for the Australian lifestyle...with over 3.4M Australians recreational fishers

3. Marine parks are less than optimum without fish! – time to also take an ecosystem approach to marine biodiversity conservation

4. Multiple other benefits – flood control, waterbirds, biodiversity, buffering, water quality, carbon sequestration

RESOURCE ALLOCATION – After we enhance productivity



Within Estuary Repair - If oyster and mussel reefs were the Great Barrier Reef...."functionally extinct"

Oyster and mussel reefs –

within estuary multi-dimensional habitat and purification systems

e.g. basis to re-establish Port Phillip snapper fishery

R&D – Ecosystem Ecology & Responses

Estuary event management for landscape optimisation

Tidal hydrology and repair of estuary morphology

What is the estuary productivity + how should this be used to improve fisheries management, including resource sharing?

Priority locations – do they exist for Australian inshore species?

The freshwater–brackish–saline interface and net primary productivity?

Larval recruitment – has it been influenced by training walls and other structures?

R&D – Human interactions with estuarine systems

Mixing the public & private benefits of estuary and wetland conservation – should fishers and the community that consume seafood pay farmers for habitat repair on private lands?

Sustainable fisheries management – should this be based on habitat condition and the habitat's potential for productivity?

Fostering local stewardship – what works?

Understanding and valuing the multiple outcomes that accrue from good estuary management

Policy, legislation and regulations – what works?

Resource sharing within repaired estuarine environments

R&D – Sustainable Fisheries Management

* What is sustainable yield [across all component stressors]
* Smart systems for predicting population fluctuations / productivity shifts and to underpin entitlements
* Resource allocation between sectors and smarter outcome orientated regulations
* Trusts / income generation / investment strategies

$ - what are the possibilities - REPAIR

* Senator Colbeck championing but little uncommitted $
* Hunt's office still coming up to speed in knowledge + also multiple groups lobbying for a small likely allocation
* Habitat Network + Oceanwatch + NRMs + Wetland Care etc all thinking through their role
* Focus might be project by project
* Important to pick winners and readily demonstrate benefits

$ what are the possibilities - R&D

* Should any major works projects get funded then FRDC MIGHT provide specific R&D funds – monitoring / evaluation / benefits / extension of lessons learnt and so on [eg oyster and mussel reefs]
* $100M election promise – say FRDC gets 15% [expect say 30% to the proposed Northern Aust. Initiative]
* Suggestion is $15M for 3 key areas:
  - i) recreational fishing survey & improving rec fish experience
  - ii) by-catch minimisation / product quality assurance
  - iii) fisheries productivity and habitat / smarter fisheries mgt
* Nothing definite – we might get zilch given drought / agric focus / forestry in Tasmania and other political imperatives…????

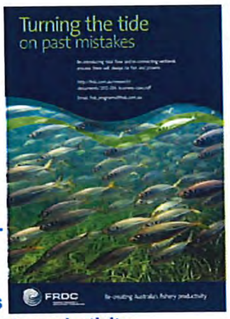
1 - Massive losses in productivity

2 - Changes to resource now almost forgotten

3 - Poor understanding of repair opportunities

4 - Fisheries management needs a re-think

5 - Focus to demonstrate the benefits



Estuaries & wetlands repair – key to productivity

Revitalising Australia's Estuaries

- multiple benefits if we can meet the challenges of turning the tide on past mistakes

Estuaries & wetlands repair – key to productivity

Clarence River – 2013 Flood Event:

Everything dead - benthic sampling from Grafton [below tidal limit] to ocean [some 90 river km downstream at Yamba].

This image – de-oxygenation and acidic effluent from drained wetlands killed all worms generally found in sediments

Estuaries & wetlands repair

– key to Australia's productivity with multiple benefits

* Jobs
* Lifestyle
* Biodiversity
* Food security
* Balance of trade
* Health

But......how do we gain investment?

The state of play

1. For Australia's estuary dependent fisheries **our resource has markedly declined**

2. Many of us have already worked hard to protect fisheries habitat and to repair our estuaries - **much excellent work and research to build on**

3. However to make major gains in productivity we need **major leadership, strong partnerships & targeted investment**

4. To gain political and community support for major investment in estuary and fisheries habitat repair we need **clear and unambiguous benefits well exceeding the costs.**

The *Revitalising Australia's Estuaries* proposal:

❑ Planning works -	$21M	[6%]
❑ Works -	$238M	[68%]
❑ Monitoring -	$24.5M	[7%]
❑ Reporting-	$10.5M	[3%]
❑ Communication & Legacy	$17.5M	[5%]
❑ Policy development	$17.5M	[5%]
❑ Research& Knowledge	$21M	[6%]

Total of $350M with break-even on investment estimated at less than 5 years using just a selection of increased commercial catch rates.

Thematic Repair Priorities

* **Restoring connectivity and fish passage** – barrages, blocks, inadequate culverts, causeways
* **Restoring estuary processes** – especially tidal and freshwater flows and fluxes, ph and oxygenation
* **Repairing drained floodplain wetlands** – removing or manipulating barrages to allow tidal water and wetland recovery and reshaping landforms to remove drains and levees, especially for acid sulphate
* **Re-establishing mussel and oyster reefs** - key within-estuary nursery through to adult fishery habitat as well as performing a water quality improvement function
* **Re-establishing seagrasses** – replanting of initial re-colonizers especially in the SA gulfs and the provision of seagrass friendly moorings

South Australian Priorities

* **Coorong, Lower Lakes & Murray Mouth –** smarter barrage operations, re-connecting island creeks and overall aiming to increase the brackish zone

* **St Vincent and Spencer Gulfs–** seagrass re-establishment accompanied by continued investment to reduce catchment sourced deleterious water quality

* **Coastal Embayments and wetlands–** especially salt marshes and re-connecting tidal flows

* **South East Coastal Lakes- Lake Bonney SE and Lake George –** fish passage, connectivity and improved tidal flows

Productivity and the Value Proposition

- break-even analysis, justifying the benefits of major investment

Estuaries & wetlands repair – key to productivity

Summary Assumptions

A subset of regions - only selected regional fisheries analysed

A subset of species - only selected species within these regional fisheries and only using projected improved returns from commercial catch

$ Value as at 2013 retail value - $value used was 'at Retail' in 2013 to capture all the benefits along the value chain from fisher to processor and market to consumer.

All non-market benefits ignored – e.g. recreational & indigenous fishing, biodiversity, landscape amenity, flood management, lifestyle improvements, water quality, flood control, coastal buffering, carbon sequestration

Biological response only starts at the end of the investment period -fish populations do respond rapidly so there will be substantial ecological benefits before that time

Summary Assumptions [cont]

No improvements in technology of capture - methods of catch and aquaculture practices + entitlements and fisheries management arrangements assumed static

Demand to be totally elastic and the benefits of Australian product replacing imported product not included - domestic demand expands to take up all the additional seafood productivity. No account was taken of the improvements to Australia's balance of trade.

Market conditions as at 2013 - no increases in value factored in from such as consumer price index or for buyer preference for the fresher Australian product.

Catch share to broadly stay as for 2013 - the current partitioning of stock between wild-caught professional product, recreational catch and remaining uncaught wild population was estimated

A single regional fishery – the Coorong Murray mouth fishery

Selected commercial species - Mulloway, Yelloweye Mullet, Black Bream & Greenback Flounder

Estimated productivity value increases – set at 20%, or about $0.26M per annum increased value of product

Break-even point compared to estimated works cost – about 7 years

Multiple other benefits – e.g. Cockles, biomass such as Congoli, migratory waders and other World Heritage values, Ngarrindjeri culture

Improving the brackish mixing zone in southern Coorong is estimated to at least increase target commercial species by 20% annual sustainable catch

increased commercial landings will equal approximate cost of works in less than 7 years

A State - NSW & floodplain dominated estuaries

Selected commercial species - Sydney Rock Oysters, School Prawns and Mullet

Estimated productivity value increases –about $94M per annum increased value of product

Break-even point compared to estimated works cost – less than 3 years

Multiple other fish species benefits – e.g. Eastern King Prawn, Yellowfin Bream, Dusky Flathead, Luderick, Mulloway, Garfish, Eels and Whiting

+ water quality, flood control, waterfowl and beef grazing productivity

Floodgate and drain removal Clarence floodplain – **soil carbon + biodiversity + productivity + fishery + water quality**

Business as usual is drained poorly productive wetlands.....

An iconic region - Great Barrier Reef

Selected commercial species - Tiger and Banana Prawns

Estimated productivity value increases –about $45M per annum increased value of product

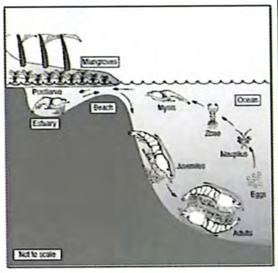
Break-even point compared to estimated works cost – less than 2 years

Multiple other fish species benefits – e.g. Barramundi, Mangrove jack, Estuary Cod, Red Emperor and flow on food chain benefits

+ Reef water quality, turtles and dugongs [seagrass improvements], tourism, indigenous culture and all related World Heritage values

Example – GBR, Tiger & Banana Prawns

- reinstatement of salt marshes and related sandy, muddy and seagrass channels along the GBR coast would probably quadruple prawn catch



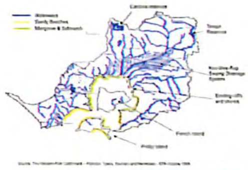
5 key messages

1. **Fisheries productivity** - our resource has markedly declined
2. **Change in our estuaries** – the next generation do not realise what is gone
3. **Understanding the repair opportunity** – our policy makers and advisors and community lack understanding of the opportunity
4. **Fisheries management** – time to understand the causes of productivity decline are NOT fishing
5. **Focus** – we need to capture the public's imagination with some clear sucesses

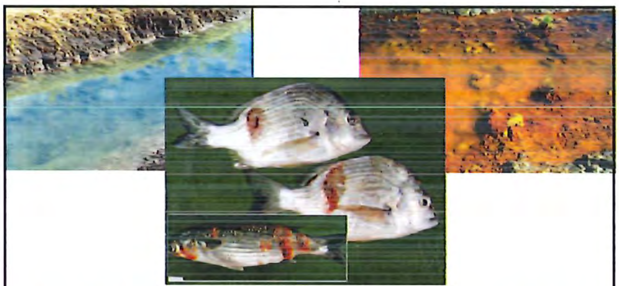
1 Fisheries Productivity e.g. - Richmond floodplain – massively drained for low value grazing



NSW – the basket case in wetland drainage and acidic deoxygenated effluent

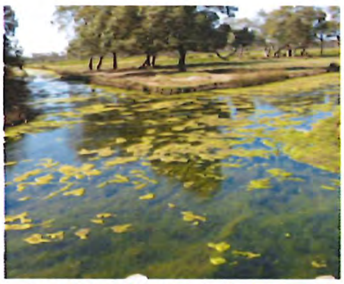



2 Change - e.g.Westernport, Vic



- Repair the wetlands to minimize fish disease and oyster deaths


Big Swamp, Manning – pollution could be fish production



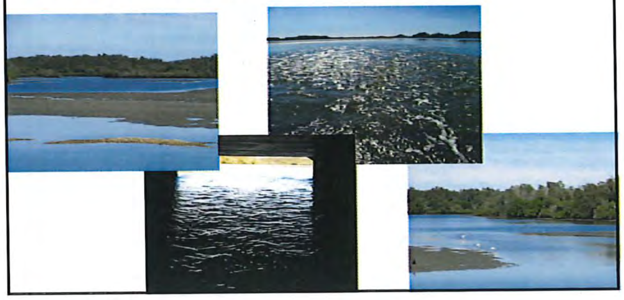
- Levees, drains, algae & de-oxygenation – how to start a "black water event", a fish and prawn kill .....OR ...trash the levee.

Acquisition + Repair - Everlasting Swamp & Sportman's Creek

- Tidal flow repair e.g. Shallow Channel, Clarence

- 2 box culverts
- Green slime and mud to sand spits, high tidal flow and fast food zone

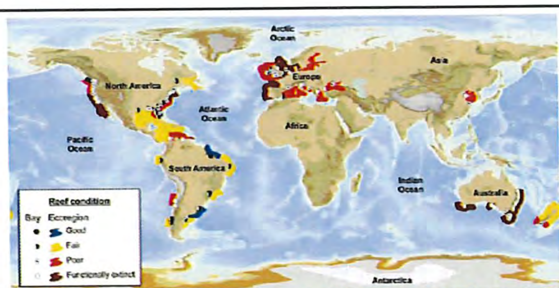
Shallow Channel, Clarence



Seagrass repair

Example: "crop circles" around moorings

Incentives for transition to seagrass friendly moorings and then regulate



Within Estuary Repair - If oyster and mussel reefs were the Great Barrier Reef...."functionally extinct"

Oyster and mussel reefs –

within estuary multi-dimensional habitat and purification systems

e.g. basis to re-establish Port Phillip snapper fishery

4 Fisheries Management

1. Over 70% of our commercial catch species have an estuary dependent phase – CPUE is not reflecting the main threats to our inshore fisheries; habitat loss, not effort is driving down population abundance

2. Probably 80% to 90% of recreational catch is estuary dependent – estuary fisheries provide for the Australian lifestyle...with over 3.4M Australians recreational fishers

3. Marine parks are less than optimum without fish! – time to also take an ecosystem approach to marine biodiversity conservation

4. Multiple other benefits – flood control, waterbirds, biodiversity, buffering, water quality, carbon sequestration

RESOURCE ALLOCATION – After we enhance productivity

Our policy & investment environment

Challenging....or perhaps its just "character building"!

* limited Aust. Govt. $ in environmental repair and many worthy opportunities
* likewise limited $ and many competing needs in States
* "infrastructure" is narrowly defined as "roads"
* food security seems to always forget the healthiest protein that does not need fertiliser or cultivation
* Australian fisheries painted negatively by simple messages on global fisheries
* as a community we readily eat imported catfish as the cheap seafood while neglecting the opportunities to re-establish such as *M. cephalus*

Our policy and investment environment [cont.]

There is a potential alignment of opportunities:

*$100M election commitment to RDCs that will be managed thru DAFF

* strong developing public – private partnerships [eg Fish Habitat Network, NGOs, US and UK examples]
* recognition that habitat repair is essential [e.g. recreational fisheries licence revenue re-investment programs in states]
* move towards "Trusts" starting with Great Barrier Reef
* capacity in agencies as demonstrated by National Estuary Network
* capacity and strong interest in the R&D community

5. Focus – my thoughts for where to now...

My suggested criteria for a set of key projects for a phase 1 -

1. Each project is <u>large in scale and vision</u> to capture public support and media attention......and MUST be achievable
2. Need <u>multi-partners</u> across public and private sectors - contributing $ and commitment
3. Projects should lead to major productivity improvements in an iconic fishery / enhanced biodiversity / community lifestyle
4. Must have <u>high</u> likelihood of success and <u>low</u> risk
5. Must be coupled with R&D and monitor change to demonstrate success.

The very draft suggestion

A "Phase I" Strategic Package across R&D + Works could be -

* GBR – ponded pastures
* SEQ – seagrass friendly moorings
* NSW – floodplain repair [Clarence and Richmond]
* Vic – Port Phillip oyster / mussel reefs
* Tas – D'Encastreaux oyster / mussel reefs
* SA – Gulf seagrasses and Lake Boney SE
* WA – Vasse – Wonnerup system repair
* NT – protection policy, suggested legislation and offset protocols

In brief:

* <u>Focus</u> to demonstrate the vision
* <u>Align</u> R&D and Works to ensure success
* <u>Monitor</u> to demonstrate ROI
* <u>Collaborate</u> as exemplar public-private partnerships
* <u>Promote</u> to position for phase II $ investment.

Estuaries & wetlands repair – key to productivity