Revitalising Australia's Estuaries

FRDC Project No. 2012/036
Biodiversity Fund Project No. LSP 942260-580

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OBJECTIVES:
Objective 1: *Use case studies in NSW and Qld that build on previous activities and that demonstrate the multiple benefits and opportunities for further investment in connectivity & wetland repair*

Four pilot estuary systems, two in NSW and two in Qld were investigated for the Biodiversity Fund investment of $200,000 in works. All pilots raised issues and lessons that were essential to the formulation of the Australia-wide business case and must be accounted for and managed in the roll out of any major investment. In brief these key issues and lessons learnt include:

- Initial fish re-population by at least some "pathfinder" species [e.g. barramundi, mullets, crustaceans] can be relatively rapid. The pilots were of too short a duration to estimate the time lag until climax community assemblages and populations would be present. Likewise, predictions on the likely fisheries productivity enhancement over time could not be predicted from these one-year pilots.
- Initial salt impact on freshwater weeds can be equally as rapid. Re-colonisation by typically estuarine plant assemblages was not as rapid as for the "pathfinder" fish species. Longer periods of monitoring than that able to be achieved in this one-year project are required. Nevertheless, based on other studies, the natural re-colonisation by mangroves, salt marsh and seagrass species is expected over the medium term of 3 to 5 years.
- Works undertaken within wholly public lands such as National Parks to repair the landscape towards natural condition and natural processes are comparatively easy to undertake from both administrative and social license perspectives. The land/water manager is committed to repair, approval processes are generally more streamlined and community engagement is more about promoting the success of the repair works than seeking endorsement.
- What might appear to be the most simplest repair works, where the current structures are unauthorised / illegal and there has been no clear benefit stream such as irrigation use or even irrigation licenses paid up to date can prove to be

impossible to rectify in the short term. The difficulty in rapidly gaining approvals to undertake repair works can be compounded if the local Authority is risk adverse and / or too close to various lobby groups to make strategic whole of community decisions.

- Expediting approval processes can best be achieved through 3rd party representations to Government agencies. Recreational, indigenous and professional fishing and conservation groups will need to take a lead role in advocacy against vested interests and the overall inertia of community resistance to change if there is to be social license for repair works.
- Repair works within a predominantly agriculture dominated floodplain landscape are difficult and at best will involve substantial compromises and win-win floodplain landscapes. Where major re-thinking of floodplain management is necessary to foster multiple benefits and the return of fisheries habitat and productivity, the time taken for community engagement and to develop a social license will be considerable. Local leaders that are both visionary and advocates for change will be essential for success.
- Repair within an urban environment and where the lands and waters are earmarked for public open space and recreation are comparatively easy to implement from a community engagement perspective. The local community is often an immediate beneficiary of repair works e.g. the provision of urban fishery habitat is strongly supported by recreational groups and young fishers.

Overall, repairing even the key degraded areas of fisheries habitat remaining around Australia's estuaries will take time, often land purchase, an increased community awareness of the benefits of fishery habitat, locality by locality social licenses and most importantly a rethinking of the private benefit versus public benefit paradigm that has driven most of the adverse landscape change, especially agricultural development.

Objective 2: *Develop an Australia-wide business plan suitable for 5 year investment that focuses on the remedial works, activities, planning, institutional arrangements and legislation to retain and repair ecological function in estuarine and wetland ecosystems*

and

Objective 3: Present within 12 months the business case to a wide range of government, industry and community stakeholders so that understanding and support is fostered for the proposed investment initiative

and

Objective 4: Capitalise on a whole host of prior research and wetland mapping activities so that the Australia-wide business case is well foundered and demonstrates the return on investment from repair activities

The Australia-wide business case was prepared in two parts:

- Great Barrier Reef estuaries and coastal wetlands; and
- Australia-wide, including chapters for NSW, Vic, SA, WA and Tas, the Northern Territory and for Queensland, a chapter on southeast Qld, being the non-GBR estuaries and nearshore assets.

This approach was undertaken at the request of the Australian Government and its Reef Rescue team, expediting completion of the Great Barrier Reef component to provide the science base and strategic direction for what then became the investment of up to $40M in "Systems Repair" as part of the Great Barrier Reef, Reef Rescue II

package.

For Australia, the business case was completed as a draft and provided to both Ministers and shadow Ministers well prior to the 2013 Australian Government election. This Australia-wide business case was finalised following input from state counterparts in August 2013. Three science papers separately funded by FRDC underpin the break-even point analysis for return on investment, being case studies for the Murray, NSW inshore and GBR prawn fisheries.

Both business cases drew heavily on prior research and involved teamwork with key Australian and state agencies, natural resources management groups and both recreational and professional fishing groups.

All research and pilot works activities were undertaken within the context of three longer-term outputs -

- To repair, where practical, the productive function of estuarine and wetland ecological systems – on a national basis for all beneficiaries (fisheries, biodiversity, water quality, carbon sequestration and recreational amenity);
- To develop suitable delivery models that build on local conditions and needs and provides for works, maintenance, planning, governance and protective management of Australia's estuarine and wetland assets (there are multiple delivery models that can be capitalised on including Reef Guardian, Indigenous partnerships, lead state & local government agencies, NRM groups, fishing industry groups, community groups, Oceanwatch Australia, Wetland Care Australia);and
- To advocate market driven mechanisms that capitalise on carbon and other markets to sustain this initiative.

Repair work is now underway on a more strategic footing in the Great Barrier Reef estuaries through the investment in "Systems Repair". In terms of delivery models, as demonstrated by the varied institutional background of the participants in this project from across the states and their regions, clearly leadership and delivery may take multiple forms. As found in the pilots, the rapidity of delivery will also vary, especially as a function of the local community and their attitudes to landscape repair for public benefit.

The broad types of repair advocated in the business cases includes:

- **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 soils thereby re-creating habitat and also removing the pollution from acidic deoxygenated runoff waters
- **Re-establishing mussel and oyster reefs** - key within-estuary nursery through to adult fishery habitat as well as performing a water quality improvement function
- **Seagrass re-establishment** – re-planting of initial colonisers especially in the SA Gulfs and the provision of seagrass friendly moorings in the heavily used recreational boating embayments of NSW and South East Queensland.

Recognising the flow-on public good that follows estuary repair, it is likely that initial investment Australia-wide, as with the Great Barrier Reef, will need to be fostered

through Government with management then devolved to various groups of beneficiaries. Because of this role for Government, the focus on investment analysis has been on estimating the likely break-even point in terms of the Australian economy for the benefits to the economy to match the investment in repair. The best and most easily calculated surrogate for Australian economic benefits is the retail price of increased commercial seafood production. Prices are readily available; the technology is already in place to harvest increased productivity; the input costs for inshore fisheries are minimal and the domestic market is demanding locally produced, high quality and reasonably priced seafood.

Projections for benefits were undertaken by examining through 3 case studies the likely break-even point for the proposed investment. Using extremely conservative assumptions, only considering the value of these selected commercial fisheries: –

- regional [Murray – Coorong];
- part of a state inshore [NSW]; and
- part of an iconic fishery [Great Barrier Reef]

the total proposed Australia-wide investment of $350M is returned in probably 3 years, certainly well less than 5 years, just from the returned productivity for the species selected from these commercial fisheries.

This return on investment is outstanding. The break-even analysis did not include the value of increased commercial product in other states such as WA, the rest of SA, Vic, Tas, SEQ and NT and indeed does not even consider all product caught in the three case study areas. No attempt was made to value recreational or indigenous fishing, yet over 3.4 million Australians claim in surveys to recreationally fish. Likewise no attempt was made to value any of the other benefits such as enhanced biodiversity or carbon sequestration; or to speculate on other potential investment streams that would increase the outcomes from Australian Government investment such as state matching contributions or private sector donations. At least in several states these co-investments are likely to be substantial from both state and local government with sources of revenue such as recreational fishing and boating licenses already allocated on a smaller scale to these objectives.

OUTCOMES

The initial project outcomes sought were:

i) Recognition of the values inherent in these coastal ecosystems, leading to increased effort to retain and protect all remaining Australian estuarine and wetland systems (as well as recognising the catchment & marine interactions, flows & fluxes); and

ii) Widespread support, understanding & collaboration across government, industry & community to foster strategic prioritised co-investment in estuary and wetland repair.

The resultant outcomes from project delivery are:

1. Strategic investment in repair for Great Barrier Reef estuaries, wetlands and riparian areas with phase I involving the “Systems Repair” component of Reef Rescue II over the following 5 years.
2. Heightened awareness in all States, within their lead agencies, their professional and recreational fishing, natural resource management and conservation sectors of the priority opportunities for repair and the benefits that will accrue from repair.
3. At least ad hoc state by state and project by project applications for funding being developed, while all recognising the advantage and benefits of a more

strategic Australia-wide initiative that couples priority works with monitoring, community awareness and research.

KEYWORDS: estuaries, nearshore, fish habitat, fishery productivity, biodiversity, repair investment, business case

2. ACKNOWLEDGEMENTS

This project was jointly and equally funded through the Fisheries Research and Development Corporation working in partnership with the Australian Government's Biodiversity Fund. The Biodiversity Fund provided the resources for the pilot repair projects. FRDC provided the resources for the Australia-wide strategic planning and business case development together with preliminary projections of increased fisheries productivity as an input to the break-even analysis.

Support and technical advice was received from all states, their fisheries, water resources and conservation agencies; Australian Government agencies such as the Great Barrier Reef Marine Park Authority, Department of Sustainability, Environment, Water, Population and Communities and the Department of Agriculture, Fisheries and Forestry; coastal natural resources management groups; fishers, professional, recreational and indigenous; conservation groups, universities and researchers.

The four pilot repair projects were lead by Reef Catchments and NQ Dry Tropics natural resources management groups in Qld and Richmond River County Council and Clarence Valley Council in NSW.

Key contributors are listed in Section 13.

3. BACKGROUND

3.1. The Problem

There are two key components to the current problem of declining inshore fisheries habitat – social alienation and unforeseen or at least ignored impact of other resource uses on coastal ecosystems. These two components are not mutually exclusive. A large part of the lack of interest or no interest in impact is due to the social alienation of the fishing sector.

- **Social alienation of a large sector of the Australian community** – Over 3.4M Australians claim to recreationally fish [FRDC 2011]. Add those involved in the professional sector from catch to services and retail and their families and the "fishing sector" is more than 18% of the Australian community. Yet a range of Australian and State Government policy decisions and management responses have increasingly estranged the Australian commercial and recreational fishing sectors since European settlement. These include:
    - the continued community perception that fishing is unsustainable; Certainly, initially in Australia's history there was uncontrolled and extensive over-harvesting of the then bountiful estuarine and nearshore resources with limited thought to the consequences or to the concepts of sustainability for long term enduring productivity [e.g. Diggles, 2013; Brearley and Hodgkin 2006; Shepherd, Bryars, Kirkegaard, Harbison and Jennings 2008]. While the community perception seems to remain, the reality is that Australian fisheries are generally sustainably managed. Certainly for all of Australia's inshore fisheries the biggest threats are habitat loss and water quality, not fishing effort.
    - most recently, the expansion in area within marine parks under a proviso that fishing is the primary impact on fish stocks; Fishers recognise that estuarine / inshore habitat degradation, especially for the nursery phase of many key species together with the overall declining health of the contributing ecological food web because of our land uses and pollution may be the key threatening processes. Additionally, there is a community perception that the political reason for reservation is to deliver on an areal target, as negotiated with the conservation lobby. [e.g. www.keepaustraliafishing.com.au].
    - the wild fishing industry, recreational and commercial has not been included in major whole-of-community policy agendas; For example, while it is well documented that fresh water inputs are a large part of biomass fluctuations, as a primary industry, the commercial fishing industry during times of drought has not been eligible for Exceptional Circumstances funding. Most recently, the fishing industry has not been eligible for funding under the Australian Government's climate initiatives yet there are major opportunities such as "blue carbon" [Lawrence, Baker and Lovelock, 2012]. There is also a perception that much of the overarching Australian and State policy for marine resources has a biodiversity conservation rather than a sustainable use focus;
    - multiple coastal, catchment and floodplain developments where short-term construction jobs and land based private benefit are more highly regarded by all tiers of Government than ongoing sustainable jobs in the fishing sector [e.g. National Land and Water Resources Audit 2002];
    - recently, as attempts have been made to temper the negative impacts of development, offset policies being at best poorly conceived and implemented, often only involving a "one off" payment for habitat loss whereas habitat can continue producing for the economy forever;
    - as all State Governments seek to reduce expenditure, resources gained from offsets being at best poorly allocated as cross-subsidies to existing operating

costs and in some cases simply becoming part of consolidated revenue of Government rather than re-invested in repairing fisheries habitat;

- in our community attitudes, the wild fishing sector being regarded as not only secondary to development but also secondary to agriculture – the other food producing industry that through its expansion and practices has caused massive degradation to fisheries habitat; This translates from community attitude to primary industry policy, institutional and agency setting through to management and to operational areas of Government such as licensing and approval processes [e.g. Johnston, Kroon, Slavich, Cibic and Bruce 2003; Harris, Batley, Fox, Parslow and Skyring 1996; Jensen, Good, Tucker and Long 2000];
- within the wild fishing sector itself, a lack of cohesion and consistent, collaborative messages from across the recreational and professional sectors, even though habitat is the one issue that should lead to a unified stronger advocacy position; and within fisheries management, an emphasis on reducing effort and increased input regulations on the fisheries without recognising that the main causative agent for decline in inshore stocks is loss of habitat, not fishing effort [e.g. Creighton, 1982; and 2013 in prep].

The key underlying fundamental issues to this "Cinderella" position for wild inshore fisheries is that Australia's economic systems favour private benefit over public benefit. Our policy and regulatory systems strongly support enterprises seeking to provide private profit, often at the expense of the public good. Industries such as inshore wild fisheries that depend on well-managed public resources have become marginalised because of the continuing decline of our public assets. Our society is largely based on private profit taking without due regard to the externalities and impact this may cause. The negative impact on our estuarine and nearshore environment is one of the casualties.

- **Ignored or at least unforseen impact and the consequences of doing nothing to repair habitat –**

Our inshore fisheries resources have declined and will continue to decline without intervention to repair habitat. Production levels are already down [e.g. school prawn [*Metapenaeus macleayi*] fishery on Shoalhaven is now non-existent (Winberg et al, 2013). There are already major fish kills in our estuaries associated with excessive wetland drainage and freshwater flows [e.g. Clarence and Richmond – 2009, 2010, 2011, 2013]. As just one example, following the 2013 event researchers from the University of New England (Ryder and Mika 2013) benthic sampled the entire Clarence estuary and found the highly acidic, deoxygenated water had killed all benthic life forms from Grafton through to the mouth at Yamba.

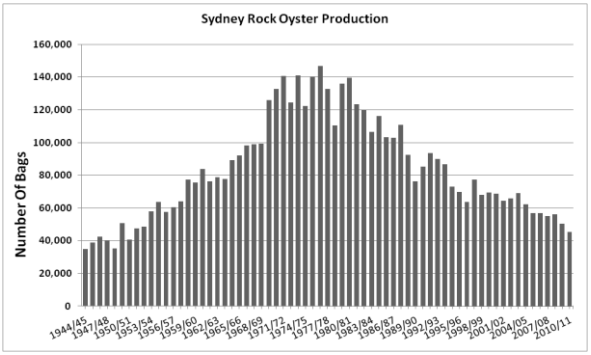
Red spot and other fish and shellfish diseases that result from animal stress are common occurrences. Most importantly we are losing the commercial sector – important for high value secure food supply and the recreational sector – important from lifestyle and tourism perspectives with multiple value adds into regional economies. [e.g. Creighton 1982; Smith 1981; Skilleter and Loneragan 2007; Government of NSW 2011;]

As an example of production losses consider Sydney Rock Oyster [*Saccostrea commercialis*] production, NSW. Sydney Rock Oyster has been chosen as the example because it is cultured in a fixed location in the lower estuary, its production levels and organism health integrates impacts from the entire estuary and by being cultured, aspects such as effort and climate influences on abundance are not as variable compared to that for other wild fisheries. The figure displays the total NSW Sydney Rock Oyster production per annum. Improved cultivation techniques were increasing production up till the 1970's. [Kirkendale, Winberg, Rubio and Middelfart in prep, 2013],

However wetland loss, drainage and overall loss of estuary net primary productivity have meant production since the 1970s has markedly declined. This is in spite of further improvements in growing technology, enhanced genetics and increased consumer demand and price. Many estuaries have now been totally abandoned as oyster growing areas and in other estuaries the more resilient Pacific Rock oyster is replacing Sydney Rock. Now with the recent spate of floods causing stress, like the QX phenomena on Sydney Rock Oysters we are also seeing major kills

of the more resilient Pacific Oysters [www.oysterhealthsydney.org and Paul-Pont I, Dhand NK and Whittington RJ 2013].

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

A second example is the NSW prawn and scale fish fisheries. School Prawn and Eastern King Prawn [*Penaeus plebejus*] catches in NSW are considered fully exploited or overfished respectively at only 75% of the catch rates that were maintained historically during the 1970's - 80's. Some rivers now only support recreational catches (e.g. Shoalhaven River). Similarly the Estuarine General Fishery has never surpassed Dusky Flathead [*Platycephalus fuscus*] average catches that were maintained in the 60's and 70's [NSW Industry & Investment 2010]. Some of this decline could be due to improvements in the rigour of fisheries management to ensure long-term sustainability. However broad and consistent trends for most species in wild fisheries indicate other underlying factors, specifically limitations to recruitment due to loss of habitat and reductions in water quality [Creighton,1982]. Much of the water quality decline, especially pH, heavy metals and anoxic or low dissolved oxygen conditions is due to the draining of floodplain wetlands. Repair the habitat and water quality will also improve [Restore America's estuaries 2012,2013; Wood 2007; Government of South Australia 2009, 2012; Grabowski and Peterson 2007;].

Historically, fisheries habitat within estuaries, their floodplains and wetlands has been lost or altered, often imperceptibly through a myriad of small decisions and because works such as drainage, roadways, causeways, training walls, floodgates and levees did not consider these more public assets of fisheries production. Floodplain areas have been developed for a single objective – additional lands for agriculture. Yet in most cases we have ended up with wastelands between agriculture and the estuary that are neither useful for agriculture nor beneficial to estuary productivity. Many works such as levees, floodgates, culverts, causeways and drains were less than optimally designed and often poorly located. Through strategic works we can repair key parts of the landscape, often optimising both fishery production and floodplain agriculture. [e.g. Johnston et al 2003; Environment Protection Authority 2003; Goodrich 1970; Government of South Australia 2009, 2012; Alburto-Oropeza O, Ezurra E, Danemann G, Valdez V, Murray J and Sala E 2008;]

Indeed, during this project the author, with a childhood spent around the Clarence, was struck by the polarisation of community awareness on estuary and nearshore productivity. Other, older managers and fishers could recount the post World War II period up to the 1970's of generally higher levels of productivity whereas the much younger researchers, managers and fishers are accustomed to the much reduced productivity of the 1980's, '90's and onwards. If nothing is done to repair habitat, the current conditions will become the norm and presumably further decline will be accepted.

To conclude, as Aristotle famously noted in the 4th century BC –

> "That which is common to the greatest number has the least care bestowed upon it".

4. NEED

4.1. Ecological and Community Context

Three key concepts underpin the imperative to repair estuarine and nearshore habitat – the estuarine dependence of the vast majority of fish stocks Australia seeks to utilise as a sustainable food and recreational resource; the importance of estuarine and nearshore areas to the Australian lifestyle; and their importance to overall aquatic, coastal and marine ecosystem health and biodiversity conservation.

- **Estuarine Dependence** - Virtually all the target recreational species and about 70% to 80% of commercial target species are dependent on a life cycle phase within estuaries and wetlands so any works to repair habitat will be of substantial fisheries benefit, including long term protein production, or food security. [e.g. Pollard,1976;1976a); 1994; Copeland C and Pollard D 1996; Bryars S, Neverauskas V, Brown P, Gilliand J, Gray L and Halliday L 2003; Jerry D 2013; Lloyd D 1996; NSW DPI 2007, 2008;]
- **Community Access** – Much of the recreational effort, especially such as family fishing occurs within estuaries. Repairing the productivity of Australia's estuaries will have massive flow on benefits to regional tourism, local economies and the Australian lifestyle.
- **Marine Biodiversity Linkages** – with estuary dependence dominating the life cycles of most Australian fish and prawn stocks, any marine park dedication will not meet its conservation objectives unless all the life cycle components of the stock the park seeks to protect are robust and the habitat supporting all the life cycle components is in good condition. Estuary habitat is the missing link. Repairing estuary habitat will not only benefit commercial and recreational fishing but will ensure the resilience of all marine park dedications.

4.2. Habitat repair – the missing components to healthy fisheries

The three interlinking components to healthy fisheries are habitat, water quality / quantity and fishery management. Fisheries management through Government agencies policy, legislation and regulations coupled with correspondingly improved professional and recreational behaviours have come to the party and delivered improved fishery management in all states. By-catch is minimised, most spawning aggregations are excluded from fishing pressure through spatial and temporal closures, impact on habitat from fishing gear and on non-target species is much reduced and in many fisheries is minimal, and virtually all Australian fisheries have been assessed as sustainable from the perspective of catch as a proportion of available stock and appropriate age classes for harvest.[FRDC 2011 together with various sustainability assessments and Marine Stewardship Council certifications – see www.msc.org]

Point source water quality such as from sewage treatment works, abattoirs, foundries and heavy industry has also been increasingly minimised and regulated with consequent improvement in water quality. A good example within this project is the progressive improvement of water quality in Lake Bonney, South East, [Environmental Protection Authority 2003;] In this example the decline in fishery productivity was due to both the manipulation of the ocean entrance of the lake system to ensure a year around water source and the use of the resulting water body as an effluent dump for paper pulp mills. In the case of Lake Bonney, with pulp mill waste management now markedly improved, it is timely to consider repairing the previous manipulation works that markedly reduced fishery connectivity. Similar improvements in water quality management are found across Australia's major cities and industrial centres such as the improvements underway over many years for Port Phillip from dumping ground for industrial effluent to major asset [Harris et al 1996;].

Diffuse source water quality decline at the catchment scale has been addressed since the 1980's in most states with the implementation of catchment management initiatives and in many states Catchment Management and/or Natural Resources legislation. Much remains to be done

as attested by the progress of Reef Rescue I and now Reef Rescue II in the Great Barrier Reef catchments. [e.g. www.reefplan.qld.gov.au; Great Barrier Reef Report Card, 2011;]. Nevertheless sediment, pollutants and nutrients from upper catchment areas around Australia are markedly reduced. With overall water quality now improved around Australia it is appropriate to re-establish key components of within-estuary habitat such as seagrass beds in South Australian Gulfs or the re-establishment of within-estuary oyster and mussel reefs in the sheltered embayments of the eastern and southern coasts. This is similar to what is already underway in USA, where again, both point and diffuse source water pollution is much reduced and fisheries management is in place [e.g. Kemp WM, Boynton WR, Adolf JE, Boesch DF, Boicourt WC and Brush G 2005; Kroeger T 2012; Newell RIE 2004;].

For a very few estuarine systems a total repair initiative has been implemented. Probably the best example is Wallis Lakes in central NSW that demonstrates that measureable outcomes can certainly be achieved with a focused and thorough investment in whole of system improvement. Wallis Lakes was basically closed as an oyster fishery after a hepatitis scare and poor water quality, especially from poorly performing septic tanks. After comprehensive mapping of all the creeks, rivers and wetlands that flow into the lake, agricultural runoff and acid sulphate pollution were also identified as problems. The Great Lakes Council acted quickly to remedy the septic tank effluent issue and has been using levy arrangements to buy and rehabilitate affected wetlands, especially those with extensive acid sulphate soils causing the acidic and deoxygenated inflow to the Lake following major rain events. Wallis Lake is now amongst the cleanest oyster farming areas in NSW [Great Lakes Council, 2012;].

The remaining major water quality problem across Australia that severely impacts on fisheries is acidic deoxygenated effluent that rapidly flows to estuaries from drained swamps following rain events. [e.g. Ryder, D and Mika S 2013; Government of NSW 2011;]. This water quality issue is also one of the key habitat re-establishment issues. Repair and reconnection of these swamps to the estuary will increase productivity from two respects –

- increased habitat, shelter and net primary productivity as these wetlands once again become part of the estuary;
- improved water quality, less acidic leachate and more dampened freshwater flows as the drains in these wetlands are filled in back to normal wetland surfaces and runoff is more gradual.

Connectivity loss is another part of the habitat re-establishment issue across Australia such as that caused by road bridges, causeways, tidal barrages, culverts, ponded pastures and bund walls. As an example, the Great Barrier Reef Marine Park Authority has mapped in excess of 1500 barriers to fish passage just in the Burdekin catchment. Loss of connectivity is loss of access to habitat that once ensured a greater fishery productivity for each river, estuary and its wetland complexes. These various barriers around Australia were constructed in times past when knowledge was lacking and the single focus objective was to develop floodplains for agriculture.

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 impacted on seagrasses, salt marshes, mangroves and fresh to brackish wetlands. [e.g. Goodrich BM 1970; Jensen A, Good M, Tucker P and Long M 2000; Mackenzie J and Duke NC 2011; Morrisey J 2009; NSW DPI 2007, 2008; NSW Fisheries 1999; Odum HT 1983; Thomas BE and Connolly RM 2001; West RJ Thorogood C Walford T and Williams RJ 1985; Wilton KM 2002;] A systems approach will be essential in any repair strategy so that those components of the landscapes and ecological processes most likely to improve ecosystem productivity are given priority.

Australian estuaries and wetlands have been under-valued and much of their ecological function has been lost due to a multitude of small, past decisions coupled with a lack of understanding of their importance and community benefits. We now as a community appreciate the many values of coastal ecosystems and generally the community supports their repair as a means of addressing the legacy of past decisions. At the same time, a note of caution is necessary. In many cases there has been irrevocable loss. The art form for investment will be to identify the "easy wins" - where other public or private assets are not substantially at risk, the benefits well outweigh the costs and the overwhelming community attitude supports repair works. This report

summarises the work prepared in the two business cases that identified and costed the most prospective opportunities for repair across Australia.

5. OBJECTIVES

The four objectives of this project are:

- ✓ Objective 1: *Use case studies in NSW and Qld that build on previous activities and that demonstrate the multiple benefits and opportunities for further investment in connectivity & wetland repair*

- ✓ Objective 2: *Develop an Australia-wide business plan suitable for 5 year investment that focuses on the remedial works, activities, planning, institutional arrangements and legislation to retain and repair ecological function in estuarine and wetland ecosystems*

- ✓ *Objective 3: Present within 12 months the business case to a wide range of government, industry and community stakeholders so that understanding and support is fostered for the proposed investment initiative*

- ✓ *Objective 4: Capitalise on a whole host of prior research and wetland mapping activities so that the Australia-wide business case is well foundered and demonstrates the return on investment from repair activities*

6. METHODS

6.1. Pilot Habitat Repair Case Studies

Four estuary systems, two in NSW and two in Qld were investigated for the Biodiversity Fund investment of $200,000 in works. Six locations were investigated with works to benefit fisheries habitat completed in four of these sites. All pilots raised issues that contribute to the formulation of the Australia-wide business case and must be accounted for and managed in the roll out of any major investment. Full details of all locations, including maps and photos are provided in the accompanying reports. The pilot estuary systems and works projects were:

1 - Queensland

- **Burdekin / Cape Bowling Green National Park** –
  This pilot within the National Park removed a prior road causeway and demonstrated success in repair, including eradication of salt intolerant water weeds – Para Grass [*Urochloa mutica*] and Olive Hymenachnae [Hymenachne amplexicauli] and re-introduction of habitat and fish – with juvenile Barramundi [*Lates calcarifer*] and Common Mullet [*Mugil cephalus*] already with the first monitoring post removing the block.

- **Burdekin floodplain, one of the many Burdekin floodplain Water Board blocks** –
  This pilot did not proceed. The Water Board, concerned about precedent of removing a bund might have on the 1500 or so other bunds on the floodplain immediately addressed the interested landholders issues of surplus fresh water dumped on his lands. The landholder then withdrew his interest in repair works. In essence, repair works were pre-emptory. Detailed landholder and Water Board involvement in a revised floodplain management plan for the multiple objectives of improved agricultural and fisheries production is a necessary precursor to repair works for the Burdekin floodplain.

- **Pioneer Urban Waterway Renewal and Re-connection** –
  This project demonstrated success in repair, including replacement of freshwater weeds with salt tolerant species and re-introduction of fish with the re-connection of the lagoons to the Pioneer River. The site was previously barraged and part of cane lands and more recently part of the Mackay urban area. Rehabilitation to natural conditions was strongly supported by local residents and Mackay Regional Council and will provide a further enhancement to biodiversity for the Mackay Botanical Gardens.

2. **NSW**

- **Clarence Major Waterway Wetlands** –

The Broadwater Creek unauthorised and illegal block is one of many along NSW floodplains. The social issues of a poorly communicative prior license holder coupled with State agency and Local Government caution in dealing with the community for the common public good demonstrated very clearly the difficulties that will be faced in restoring habitat for public benefit, even if there is no private loss. In this pilot no expenditure on works was possible and the funds were reallocated to the Richmond estuary.

- **Richmond Floodplain Management** –

The Empire Vale Creek and Rocky Creek sets of works for improved fishery connectivity and risk management against periods of de-oxygenation were well thought through by Richmond River County Council. Works were implemented with two already well-engaged communities of adjacent landholders, in this case groups of farmers with an interest in estuary health and fishery repair as well as their enterprises of cane and beef.

6.2. Australia-wide Business Case for Repair

Developing the strategies, priorities and actions for fisheries habitat repair was undertaken through an interactive process with key stakeholders in each region / state / Northern Territory of Australia.

For timing reasons associated with the Australian Government's formulation of *Reef Rescue II* and the "Systems Repair" component of *Reef Rescue II* work on the Great Barrier Reef catchments was expedited so that a draft final report was prepared by late January 2013 and the final report for Great Barrier Reef catchments completed early March 2013. In brief the steps were:

- Information assimilation, multiple sources, including published reports, GBRMPA and State agency mapping and Natural Resource Management regional strategies and water quality improvement plans
- Nomination of key contacts in each NRM region, GBRMPA and key State agencies and briefing of the task ahead, including provision of templates for data entry
- Joint work with staff from GBRMPA to prepare a draft Business Case
- Commissioning of a productivity analysis science paper, led by Prof Marcus Sheaves, James Cook University.
- Numerous interactions, discussions, phone calls and emails with fishers, fishery managers and staff from agencies and natural resource management groups
- Workshop with key contacts and other players to review the draft, agree on overarching arrangements for the management of such an initiative and processes for integration and delivery
- Briefing of Australian Government representatives from SEWPAC and DAFF, including the *Reef Rescue* Unit
- Finalisation of the business case and its circulation as an input to the development of the "Systems Repair" initiative and for each NRM and other groups to use as a reference document in the preparation of their proposals for funding from the call for projects managed through the Australian Government.

The Australia wide business case followed a similar process. In some states there were multiple face-to-face small number of participants meetings, in others more formal workshops were held but in all cases an attempt was made to capture as diverse an input as possible across agencies, fishers and non government organisations. Again an iterative process was used to capture the various inputs, with again, several drafts prepared before final documents for chapters were agreed.

7. RESULTS/DISSCUSSIONS

Following are summary responses on each of the nominated outputs for the project.

7.1. Pilot Habitat Repair Case Studies

Output 1 – pilot examples of repaired fish passage and increased community understanding and commitment to habitat repair accompanying these pilots.
This has been achieved in three of the four pilots. It has involved the engagement of multiple groups in undertaking these works and then the promotion of results across the fishing community as a lead in to promotion across the community generally. Detail on each of these case studies is provided in separate reports [see Section 12].

All pilots raised issues that were accounted for within the formulation of the Australia-wide business case and must be accounted for and managed in the roll out of any major investment. The lessons learnt pilot by pilot were as follows:

1 - Queensland

- **Burdekin / Cape Bowling Green National Park** –

Lessons are clear –

- Reintroducing tidal waters leads to rapid re-colonisation by estuarine spp;
- Working within public estate lands is relatively simple, approval processes are minimal and investment in repairing natural processes are welcome

- **Burdekin floodplain, one of the many floodplain Water Board blocks** –

In this pilot no expenditure on works was possible and the funds reallocated to the Pioneer estuary. Lessons are clear –

- Whole of floodplain context is essential and a whole of floodplain stakeholder engagement process is needed, probably in this case managed through the two Burdekin Water Boards
- Rationalising irrigation tailwater management and ensuring all farmers also benefit is essential – and implies that any major initiative must deliver both agronomic and fishery benefits
- Several years planning, especially community awareness and building support for multi-objective floodplain management will be required
- Local visionary leaders and advocates will be essential for success

- **Pioneer Urban Waterway Renewal and Re-connection** –

Lessons are clear –

- Well thought through planned projects in partnership with Local Government and with an already well-engaged community of adjacent landholders, in this case urban dwellers are comparatively easy to implement
- Urban beneficiaries such as recreational fishing groups and young fishers strongly support enhanced habitat in their locality
- Linking to existing parks and open space areas, in this case the Mackay Botanical Gardens ensures a broad spectrum of supporters for landscape repair

2. **NSW**

- **Clarence Major Waterway Wetlands** –

In this pilot no expenditure on works was possible and the funds reallocated to the Richmond estuary. Lessons learnt included:

- Public good activities must be very compelling and must be strongly advocated if they are to be made a priority for scarce resources within agencies
- Social issues, not previously predicted or appreciated can de-rail good intentions (in this case a non-communicative, health-challenged prior license holder)
- Advocacy and substantial community support is also a precursor for Local Government to make strategic repair decisions for the overall public good
- In brief, while such repair works re-establish what should never have been lost, fisher advocacy and high public profile is essential for success

- **Richmond Floodplain Management** –

Lessons learnt included:

  - Working with rural landholders that are already committed to maximising multiple benefits from the floodplain landscape are comparatively easy
  - A committed and "can do" agency, in this case the Richmond River County Council, ensures rapid and practical success
  - Such works, while minimising the risks of fish kills do not greatly repair and extend the available habitat and therefore improve overall fishery productivity only in that there are reduced kills of the existing fish population.

Output 2 - Australia-wide Estuary and Wetland Repair Plan & ***Output 3 - State based business cases***

These two outputs were achieved through the Great Barrier Reef and Australia-wide business cases.

7.2. Great Barrier Reef Business Case

Key points to note are:

- The Great Barrier Reef is more than the coral reefs – seagrasses, mangroves, salt marshes and brackish to freshwater wetlands are essential parts of the reef ecosystem.
  Example: Coral trout [sp] spends its nursery phase within nearshore and sometimes lower estuarine environments. Without a healthy nursery there will be fewer adult fish with flow on implications to coral ecosystems, commercial and recreational fishing, diving and snorkelling experiences [Pratchett MS, Messmer V, Reynolds A, Martin J, Clark TD, Munday PL, Tobin AJ and Hoey AS 2013].
- Many of those that enjoy the Great Barrier Reef do so through their activities in the coastal zone – fishing, recreating, bird watching or just relaxing.
  Example: Much of the life history of the Mangrove Jack [Lutjanus argentimaculatus] is played out in the estuary [Russell, D.J 2003].
- Indigenous use of the Great Barrier Reef is focused inshore.
  Example: Seagrass ecosystems and their dugong and turtle populations [Coles RG, Lee Long WJ, Watson RA and Derbyshire KJ 1993]
- There have been many unforseen impacts of floodplain development. Works undertaken in the past occurred without knowledge of the interlinked ecosystems.
  Examples of works: wetland drainage, roadways and causeways restricting tidal flow, floodgates and bunds prohibiting fish passage, levees altering tidal and floodwater flow, ponded pastures isolating salt marshes from the estuaries;
- With the knowledge we now have we can repair key elements of the Great Barrier Reef's estuarine and inshore ecosystems, optimising community returns from the coastal landscape
  Examples of benefits: increased fisheries production, improved coastal water quality, flood proofing; infrastructure; enhanced biodiversity such as more waterfowl and migratory waders; increased carbon sequestration

The business case set out the rationale and the priority opportunities for investment, repairing under a 'no regrets' policy, estuary and wetland areas along the Great Barrier Reef catchments. It seeked to maximise community benefits from these important parts of our landscape while minimising costs and impacts on adjacent land users of the coastal zone.

The business case was built on cooperation across the Great Barrier Reef community and its many stakeholders and suggested co-investment from all tiers of government and the community.

7.2.1 The gap in Great Barrier Reef ecosystem repair

Essentially the business case filled a major gap in Great Barrier Reef ecosystem repair -

Reef Rescue I is repairing agricultural landscapes – reducing erosion, improving water re-use and water use efficiency and most importantly, reducing sediment, nutrient and chemical export from paddocks. *Reef Rescue II* is expected to continue this excellent work.

Zoning plans and a philosophy of multiple use have ensured a sustainable mix of use and conservation zones for activities such as commercial and recreational fishing and tourism in the reef and lagoon.

Reduction in commercial fishing effort, both prawn trawl and inshore net, devices such as TEDs (turtle excluder devices) plus closures in some inshore areas to protect high value species such as dugong have minimised the impact on charismatic megafauna such as turtles and dugong. There are claims that the prawn fishing effort is still too high. Perhaps this might be the case if managers take a simplistic approach that looks at fishing effort as the only threatening process to sustainability. The solution that has yet to be fully assessed is the role of habitat repair in re-establishing prawn productivity. Section 8.9 of this report provides a preliminary estimate of productivity improvement possible with habitat repair.

The use of permits and codes of behaviour have ensured minimal and then only local impact from tourism and reef visitations

BUT

Estuarine and inshore ecosystems, a large part of the integrated Great Barrier Reef ecosystem, have not had a commensurate effort in improved management, especially recognising that they are the most degraded of all the reef ecosystems

7.2.2 Spring-boarding from existing community and government partnerships

All the essential elements are in place to effectively implement a major repair initiative that will revitalise the Great Barrier Reef estuarine and nearshore ecosystems and thereby ensure increased resilience and productivity for the Reef in total. Key elements include:

- Natural resource management groups have built capacity to design, negotiate and then undertake repair works in partnership with landholders such as providing watering points and managing stock access to riparian areas and salt marshes and constructing fishways.
- Local governments recognise the importance of the Reef and have capacity in engineering works such as road culverts to improve tidal ventilation and levee rationalisation for improved flood control and fish passage.
- Water supply authorities such as water boards and Sunwater have participated in repairing fish passage and are keen to seek further efficiencies in water delivery, use, re-use and quality.
- Non-government organisations of Sunfish and the Queensland Seafood Industry Association in partnership with the Queensland Government have participated in estuary repair projects such as fish passage works and are especially proficient at monitoring the improvements in biodiversity that accompany repair works.
- Local marine advisory committees and Great Barrier Reef-wide advisory committees are well linked into their communities such as identifying priorities for action.
- Researchers within James Cook University including previous Queensland Government entities such as the Seagrass Unit have internationally recognised skills in both research and monitoring of coastal ecosystems.
- Queensland and Australian governments in partnership have developed and coordinated delivery of actions and activities to Reef Plan I and II and are in the processes of preparing the strategic overview for reef repair and management as part of Reef Plan III.

- The GBRWHA Strategic Assessment is looking for a way forward in identifying actions towards a more sustainable reef system.

The management challenge now is not only to ensure that any future development in and adjacent to the Great Barrier Reef World Heritage Area is ecologically sustainable but also to repair past mistakes in development. A legacy of past development and land use practices has led to degradation of Great Barrier Reef estuarine and nearshore ecosystems and water quality and very marked declines in inshore biodiversity. Management actions are required to halt and reverse these declines and to restore the ecological functions and productivity of estuarine and nearshore ecosystems

The Great Barrier Reef catchment is a complex jurisdictional environment and the arrangements applying to coastal zone management are often unclear. Collaborative arrangements established under an inter-governmental agreement for the management of the Great Barrier Reef and their catchments ensure an integrated and collaborative approach by the two governments to the management of marine and land environments within and adjacent to the Great Barrier Reef World Heritage Area. This agreement provides for:

- long-term protection and conservation of the environment and biodiversity of the Great Barrier Reef ecosystem, as encompassed by the Great Barrier Reef World Heritage Area, and its transmission in good condition to future generations
- allowing ecologically sustainable use of the Great Barrier Reef ecosystem subject to the overarching objective of long-term protection and conservation
- Australia's international responsibilities for the Great Barrier Reef World Heritage Area under the World Heritage Convention.

Economic growth and the long-term health of the Great Barrier Reef ecosystem are interconnected. Actions or changes in one can impact on the other and must be taken into account, in particular:

- population growth and economic development increases the demand for resource and recreational use of the Great Barrier Reef
- land-use activities in the catchment can have adverse impacts on the quality and quantity of water entering the Great Barrier Reef
- initiatives to reduce external pressures on the ecosystem can have regional and local social and economic effects, and improve the long-term viability of the region.

Development will continue. Even with the best of planning and controls, some localised degradation will have to occur to allow development to meet the communities' many economic and social objectives. Investment in repair provides a much needed buffer to any localised losses that will accompany development such as port works so that there is a net ecological gain.

Implementation of this business case for estuarine and nearshore ecosystem repair will be achieved through cooperation across the Great Barrier Reef community and its many stakeholders, seeking co-investment from all tiers of government and the community. Involvement with stakeholders will need to be coordinated to maximise efficiency and consistency, reduce duplication, and will demonstrate the willingness of the community to adopt a collaborative and solutions-oriented approach.

It is through these groups and their activities that significant on-ground repair to these critical public assets can be implemented and changes of attitudes and behaviours achieved to ensure their long-term protective management. As in all investments, the challenge is to ensure the resources available are targeted at the most critical areas for improved long-term community benefits. The business case sets out the protocols and processes to facilitate maximum return on investment.

The investment will also identify how overall benefits can be incentivised into the future, empowering industry groups, private landholders, local governments and regional natural resource management groups to continue to manage the repaired assets that a five-year Australian Government investment delivers. Offsets for development can be part of this solutions-oriented approach.

The Great Barrier Reef region was inventoried and assessed based on each of the natural resources regions: Burnett–Mary, Fitzroy, Mackay Whitsunday, Burdekin Dry Tropics, Wet Tropics and Cape York. This included a summary of current condition and a listing of the key repair opportunities for each region.

The final proposal in summary is provided in Table 1:

Table 1: Proposed Budget allocation to broad cost areas, Great Barrier Reef catchments.

	Cost ($M)	**Proportion of total** (%)
Planning– all aspects to ensure approvals, undertake surveys such as tidal penetration, document proposals and likely return on investment of each proposed project	$5M	8%
Works, generally under some form of tender/contract arrangements with the owner– including fish passage, estuary and wetland repair and complementary works to ensure smarter floodplain and estuarine ecosystem management	$40M	69%
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	$5M	8%
Reporting progress – summarising the outputs and longer term likely benefits/outcomes of the total investment, undertaken annually and including an evaluation of progress in Year 4.	$2M	3%
Program communication, legacy arrangements & marketing – building on existing communication activities such as the natural resource management and Great Barrier Reef Marine Park Authority planning and communications, 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 legacy arrangements modelled on Reef Guardian successes for ongoing management after this period of investment and covers oversighting activities such as expert-based steering committee and program manager	$4M	6%
Researching cost-effective repair and priority investments – building on existing knowledge of the estuarine dependence and preferred habitats of key species to predict priorities for works	$4M	6%
TOTAL	**$60M**	

To date the Australian Government has announced up to $40M to be spent on “Systems Repair” as part of *Reef Rescue II*. The first call for applications is already progressing, with many of the high priority projects listed in each of the regional assessments among the projects being proposed by regional NRM groups and others. Additionally, FRDC worked closely with Oceanwatch and James Cook University prepared a proposal for consistent and comparable monitoring of all repair activities approved as part of this investment. The previous Australian Government had foreshadowed that it will announce funding for *Reef Rescue II* research and development investment later in 2013. It is envisaged that some of the priority research projects identified in the Great Barrier Reef business case might receive funding under this companion initiative.

7.3. Australia-wide Business Case

The Australia-wide business case started with the premise that Healthy Fish Stocks = Healthy Communities. This was based on:

ecologically: Over 75% of Australia's commercial fish catch and probably up to 80% to 90% of all recreational catch spends part of its life cycle within estuaries and inshore wetlands.
Revitalising Australian estuaries will increase fisheries productivity and all aspects of coastal ecosystem biodiversity.

economically: Earning $2.2 billion a year, Australia's seafood production is the fifth biggest food industry in Australia.
Revitalising Australian estuaries will increase product available for harvest in inshore low-input–cost wild fisheries, improving industry profitability and also guaranteeing high quality aquaculture product.

socially: Over 3.4 million Australians already recreationally fish as part of their relaxation lifestyle.
Revitalising Australian estuaries will increase low-cost outdoor recreational choices, especially for our heavily populated urban centres.

culturally: All of our coastal indigenous communities rely on estuarine resources for food and custom.
Revitalising Australian estuaries will protect these renewable resources for their ongoing use.

healthily: Most of us include seafood, the healthiest source of protein and related oils in our diets. In 2007, the average Australian consumed over 23 kg of seafood.
Revitalising Australian estuaries will secure high-value low-cost food resources for all Australians forever.

This business case concentrates on repair of the more developed coastal catchments around Australia where major investment and Australian Government leadership is required to re-establish estuary productivity.

It seeks to deliver multiple benefits to the Australian community – to increase fisheries productivity, improve coastal water quality, enhance catchment hydrology, repair coastal biodiversity, fine-tune flood control, re-establish carbon sequestration and reinforce foreshore buffering against extreme events.

The business case sets out the rationale and the priority opportunities for investment, to repair and restore, under a 'no regrets' policy, estuary and inshore wetland and floodplain areas. It seeks to maximise community benefits from these important parts of our landscape while minimising costs and impacts upon adjacent land users of the coastal zone.

It builds upon the Australian love of coastal landscapes and the resources they provide and the Australian community's and political commitment to implement major natural resource initiatives such as the *Natural Heritage Trust*, *Caring for our Country* and the *Biodiversity Fund*. Like *Reef Rescue* and the *National Action Plan for Salinity and Water Quality*, the business case proposes a major focus, in this case on estuaries and their wetland ecosystems.

Most importantly, through ongoing fisheries productivity, the proposed once-off five-year Australian Government investment is estimated to return economic benefits year in and year out that will far outweigh the $350M investment of repairing these key estuary assets. The estimates suggest a break-even point for the investment of less than five years with benefits accruing thereafter.

There are many other areas of potential habitat repair not covered in this business case of the most prospective and beneficial opportunities for investment. Many of these other opportunities for habitat repair will require substantial negotiation and trade off between the benefits of conflicting land uses – especially agriculture / grazing versus fisheries food production. Nevertheless fisheries advocates equipped with the results and successes of the proposed major tier of investment would be well placed to demonstrate the benefits of further investment in these harder, often more compromised trade off between land uses opportunities.

There is also the ongoing need to enhance catchment management, especially sediments and nutrients export to waterways from diffuse sources. This is assumed to be resourced through the continuation of existing natural resources initiatives under *Landcare*, *Caring for our Country* and their equivalent state programs. The business plan recognises this ongoing investment need.

Similar to already successful schemes in USA and UK and building on schemes already underway in NSW and Victoria, this plan proposes various instruments and systems to ensure overall benefits can be incentivised into the future. This includes empowering industry groups, private landholders, local governments and communities to continue the repair of coastal assets and their management. The crucial issue is the first agenda-setting step of substantial investment in repair in the most prospective opportunities across Australia. Momentum will build and private investment will follow as indeed it has in both the USA and UK.

7.3.1 Criteria for a major initiative

In developing the Australia-wide business case the following criteria set the context -

Landscape optimisation through planning and consultation

Optimising the public and private benefits the Australian community can receive from estuarine and inshore ecosystems is challenging. Leadership and vision is essential as will need to be a strong emphasis on communication and developing shared community knowledge of the benefits to be achieved. Project-by-project detailed assessment and planning will be required to ensure maximum return on all repair investments, improving fisheries productivity and coastal ecology while paying equal attention to ensuring improvements in flood control, infrastructure and any private compensatory benefits on adjacent lands.

Capturing community commitment through leadership

There have been many small initiatives to repair parts of Australia's estuaries. Community groups, state and local government have all recognised past mistakes in our land use development of coastal zones. Most of the works and activities have had an emphasis on repairing estuarine and floodplain landscapes for multiple community public and private benefits. This Australia-wide initiative can build on the commitment and track record of these various activities.

One of the core reasons for an Australia-wide initiative is that the scale of the necessary repairs requires a major one-off investment best led and coordinated by the Australian Government. Certainly internationally, many of the programs are characterised by the leadership and vision of an initial and substantial nation-wide program-level investment followed by ongoing management and fine-tuning through local community and industry groups [e.g. Restore America's Estuaries 2012, 2013].

Ongoing management and resources

Incentivising any one-off Australian Government investment is part of ensuring its success. It is likely local management arrangements will vary from state to state. Offsets against port developments, boating and fishing licensing fees, 'blue carbon', differential rating and voluntary local action are all feasible and likely to be endorsed by regional communities. States such as NSW and Victoria already re-allocate boating and fishing licensing proceeds to works and management.

As an example, under the USA model 'blue carbon' is part of ongoing investment, the USA having endorsed carbon mitigation in coastal systems within its 'voluntary market'. Carbon sequestration from seagrasses, mangroves and salt marshes is the highest per hectare

sequestration opportunity of all Australian landscapes. [Lawrence AJ, Baker E and lovelock CE, 2012;]

Under the UK model 'local trusts' are set up to manage sections of streams and estuaries. These groups include fishers, the private sector and conservation groups.

Partnerships and Collaboration

Many groups and institutions are keen to participate in revitalising Australian estuaries. Local governments recognise the importance of recreational and commercial fishing to their regional economies. Resource management groups such as natural resources, catchment management and *Landcare* groups, and water boards recognise the opportunities to optimise production and health of their coastal landscapes. Commercial and recreational fishing groups have habitat repair and management a high priority in their policy agendas but are yet to fully collaborate on habitat repair. The Fisheries Research and Development Corporation and many states are actively involved already in habitat research and monitoring activities, albeit generally at a much lower level of activity than that proposed for this initiative.

Rollout in each state would vary in terms of lead agency and institutional arrangements. This would be finalised through negotiations as part of the proposed first year of funding building on the strengths and opportunities in each state. The first year for many works will also be a planning year, time being required to finalise approvals across the plethora of state government agencies involved in consent processes within public lands and tidal waters.

Knowledge for high return on investment and tracking progress

The Fisheries Research and Development Corporation, with its remit for both public and industry benefits from coastal ecosystems is the logical choice to oversight and co-ordinate the research, monitoring, and the reporting progress components. Section 9 suggests areas of priority for research and simple metrics for monitoring and reporting benefits.

7.3.2 Program components

Based on these criteria, key components are likely to include repair works, research, reporting, tracking progress and ensuring a legacy.

Repair works and activities

In brief, the repair opportunities include –

Great Barrier Reef estuaries and their repair are already recognised as important in a number of recent Great Barrier Reef Marine Park Authority and other reports. The focus is on reconnecting habitat and repair of the function of fresh to brackish to tidal wetlands currently isolated from tidal flows.

South East Queensland includes the same issues of connectivity and wetland repair, installing seagrass friendly moorings and re-establishing some of the historical oyster reefs within the sheltered waters of Great Sandy Strait and Moreton Bay.

New South Wales floodplain estuaries have suffered from many years of anoxic events and massive fish kills. Their coastal communities and local governments are keen to see action. New South Wales groups suggest action would be estuary-by-estuary, broadly matching local government areas and focus predominantly on the larger floodplain estuaries of Tweed, Richmond, Clarence, Macleay, Hastings, Camden Haven, Manning, and Shoalhaven.

Victorian and Tasmanian agencies and local communities recognise the need for wetland repair (e.g. Corner Inlet, Gippsland Lakes), re-establishing connectivity and both mussel and oyster reefs as the basis for multi-species fisheries.

South Australian natural resources groups, fishers and agencies suggest four key areas – Lower Murray and Coorong, the Gulfs, Coastal Salt Marsh complexes and the South East coastal lakes of Lake Bonney and Lake George.

Western Australia has a series of estuary-by-estuary water quality improvement plans for the southwest with the planning complete but insufficient resources to action these plans.

Northern Territory is predominately in near-natural condition except for centres of development such as Darwin harbour. This near-natural condition can be capitalised on and the first priority for NT is to ensure appropriate policies are in place to retain these high quality coastal landscapes.

Underpinning works and outcomes with targeted research

The importance of inshore habitat – fresh to brackish wetlands, seagrasses, salt marshes and mangroves is well recognised. Likewise the damage caused by drainage, wetland loss, nutrient and sediment loading and changed pH is documented through various case studies. Knowledge needs requiring investment includes:

- the benefits of repair and improved fisheries productivity compared to current land use as part of the impetus for change
- how best to address the dichotomy between private benefit of various estuary damaging land uses and the public benefits of estuary repair
- the relative importance of various types of estuary habitat and the various stressors such as water chemistry, temperature and hydrology on fisheries populations as input to smart habitat management decisions
- the specific habitat needs, both type and location of habitat, and the population management needs of key commercial and recreational species
- the role of key fisheries re-population nodes such as the Lower Murray for the Victorian south coast
- opportunities to recast fisheries management arrangements to include adequate consideration of production levels from coastal habitats, their local carrying capacity and the variability in populations due to variable climate and catchment run-off.

In all, 16 broad topics for research have been identified within the two themes of Ecosystem Ecology & Responses and Human Interactions with Estuarine Ecosystems.

Reporting progress and return on investment

Monitoring and resource condition assessment to demonstrate the benefits of improvements is essential. These results then need to be projected out over the following 15 years to calculate the medium-term return on investment of the works and activities. Monitoring would be done in partnership by state agencies, natural resource management groups, professional and recreational fishers and would include:

- water quality improvements (e.g. reduced pH and heavy metals and increased dissolved oxygen from repaired wetlands during run-off events and comparisons with those wetlands not yet repaired to their natural function)
- fisheries and prawn populations, especially juvenile populations in repaired tidal areas, seagrasses and wetlands with parallel monitoring in poor condition environments to demonstrate changes and to calculate overall biomass and fishery improvements
- area and type of wetland repaired and waterway area reconnected
- changes to carbon balance in a series of selected paired sites that will provide much needed input data into a methodology for 'blue carbon'.

Resource condition assessment 15 years on

The National Land and Water Resources Audit undertook the last Australia-wide assessment of Australia's estuaries in 2002. Revisiting and re-assessing under similar protocols the condition of Australia's inshore estuarine systems in 2017–18 would build on the prior work and provide an updated understanding of trends and condition 15 years on.

Priorities for any further investment post 2017–18 could be defined by combining this assessment and the findings from the monitoring activities.

Ensuring an enduring legacy through policy development

Investment towards fostering comparable policy and regulations in each state for estuarine and nearshore habitat protection, repair and for development offsets would provide the framework for ongoing management of these high value public resources.

7.3.3 Delivery as an Australia-wide program

There have been many unforseen impacts of estuary floodplain development right around developed Australia. Works undertaken in the past occurred without knowledge of the interlinked ecosystems, the benefits provided and the need for tidal flows and connectivity.

It is most important that all components of the proposed program are delivered as a package. This will maximise outputs towards outcomes at minimal transaction costs while also preparing the way for a legacy of ongoing management and protection of these key Australian resources. The indicative allocation is as follows:

Table 2: Proposed Budget allocation to broad and inter-related cost areas Australia-wide:

	Cost ($M)	**Proportion of total** (%)
Planning: all aspects to ensure approvals, undertake surveys such as tidal penetration, document proposals and likely return on investment of each proposed project	$21M	6%
Works, generally under some form of tender/contract arrangements with the owner: including fish passage, estuary and wetland repair and complementary works to ensure smarter floodplain and estuarine ecosystem management	$238M	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	$24.5M	7%
Reporting progress: summarising the outputs and longer-term likely benefits/outcomes of the total investment, undertaken annually and including an evaluation of progress and assessment of estuary condition in Year 4.	$10.5M	3%
Program **communication, legacy arrangements & 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	$17.5M	5%
Policy development: fostering comparable policy and regulations in each state for estuarine and nearshore habitat protection, repair and for development offsets	$17.5M	5%
Researching 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 post this five-year investment	$21M	6%
TOTAL	**$350M**	

8. BENEFITS AND ADOPTION

8.1. Planned Outcomes and Benefits

The long-term objectives are to
a) - Repair, where practicable, the productive function of estuarine and wetland ecological systems - on an Australia-wide basis for all beneficiaries - fisheries, biodiversity, water quality, carbon sequestration and recreational amenity

b) - To develop suitable delivery models that build on local conditions and needs and provides for on an Australia-wide basis for all beneficiaries - fisheries, biodiversity, water quality, carbon sequestration and recreational amenity

c) - To develop suitable delivery models that build on local conditions and needs and provides for works, maintenance, planning, governance and protective management of Australia's estuarine and wetland assets. [Note there are multiple delivery models that can be capitalised on including Reef Guardians, Indigenous Partnerships, lead State and Local Government agencies, NRM groups, fishing industry groups, community groups, Oceanwatch Australia, Wetland care Australia.]

d) - Advocate market driven mechanisms that capitalise on carbon and other markets to sustain this initiative

These build to overall outcomes of –

1 - Recognition of the values inherent in these ecosystems, leading to increased effort to retain and protect all remaining Australian estuarine and wetland systems and linked to this, recognising the catchment and marine interactions, leading to repair of coastal flows and fluxes

2 - Widespread support, understanding & collaboration across government, industry & community to foster strategic prioritised ongoing investment in protective works and activities, especially in the very long term. This provides a risk management strategy to deal with the potential of sea level rise. Landward movement of wetland boundaries will be required to maintain their ecological function and fish / microalgae etc. production.

8.2. Performance Indicators

Following is a summary assessment of the status of each performance indicator, as nominated in the initial FRDC application.

Objective 1 *- Use case studies in NSW and Qld that build on previous activities and that demonstrate the multiple benefits and opportunities for further investment in connectivity & wetland repair*
Performance Indicator - Fish passage restored and well promoted and supported by the community

- ✓ COMPLETED

Objective 2 *- Develop an Australia-wide business plan suitable for 5 year investment that focuses on the remedial works, activities, planning, institutional arrangements and legislation to retain and repair ecological function in estuarine and wetland ecosystems*
Performance Indicator - Business Plan developed and endorsed by key agencies and groups within each state

- ✓ COMPLETED

Objective 3 *- Present within 12 months the business case to a wide range of government, industry and community stakeholders so that understanding and support is fostered for the proposed investment initiative*
Performance Indicator - Series of applications submitted to Biodiversity Fund for assessment

and the majority of these receive funding

- ✓ PARTIALLY COMPLETED – well in progress for GBR catchments with resources under *Reef Rescue II* allocated and as yet, no specific round of funding call for the remainder of Australia. Indeed recognising Government processes and the 2013 election, it is likely it will be well into 2014 or even 2015 before the outcomes against this performance indicator can be accurately assessed.

Objective 4 *- Capitalise on a whole host of prior research and wetland mapping activities so that the Australia-wide business case is well founded and demonstrates the return on investment from repair activities*

Performance Indicator - Competent information sets accompany each State Business Case as part of the hand over from planning to works activities

- ✓ COMPLETED – each state chapter includes a priority set of works and activities

8.3. Beneficiaries and Stakeholders

Substantial contact with both beneficiaries and stakeholders occurred over the conduct of the project. Key contacts include:

- ✓ Western Australia – WA Fishing Industry Council, *RecFishWest*, the 3 southern Natural Resource Management groups from Perth around to Esperance, Department of Agriculture and Food WA, Department of Fisheries and Department of Water
- ✓ South Australia – SARDI, all coastal Natural Resource Management groups, fisheries groups and other key State agencies;
- ✓ Victoria – DPI Vic Fisheries and the University of Melbourne;
- ✓ Tasmania – working through Tas Aquaculture and Fisheries Institute / University Tasmania, the 3 Natural Resource Management regions plus recreational fishing;
- ✓ NSW – DPI Fisheries, Local Governments [Clarence and Richmond for pilots and virtually all the northern NSW coast local governments through the Floodplain Management Network as well as a specific set of interactions with Shoalhaven Council], Northern and Central NSW Natural Resource Management, Clarence River Fishermen's Cooperative, Professional Fishermen's Association, University of NSW, University of Wollongong, *Oceanwatch* and conservationists, including the reprinting of several articles initially prepared for *Fish* in the *NSW National Parks Association Journal*
- ✓ South East Queensland – working through the two coastal non Great Barrier Reef Natural Resource Management groups;
- ✓ Great Barrier Reef - Great Barrier Reef Marine Park Authority, all Reef Natural Resource Management groups, *Oceanwatch*, Qld Seafood Industry Association and *SunFish*;
- ✓ Northern Territory – working through the recreational fishing sector and Fisheries Departmental staff; and
- ✓ Three teams of scientists preparing the summary analysis of productivity declines and opportunities that underpin the break-even analysis: – Murray – Lower Lakes – Coorong, NSW and Great Barrier Reef.

8.4. Long-term benefits of habitat repair

Experience to date in Australia and principally overseas demonstrates that repair of habitat yields long-term benefits to food production, employment and lifestyle (Restore America's Estuaries, 2012). Habitat repair contributes substantially to regional economies. Due to the limited extent to date of habitat repair in Australia there are very few detailed case studies. Benefits from the Wallis lake initiative of Great Lakes council have yet to be quantified.

A recent USA report 'More Habitat Means More Fish' (Restore America's Estuaries in association with American Sportfishing Association and NOAA Fisheries, 2013) found that restoring and expanding coastal and estuarine habitat leads to increases in fish populations, and has a positive impact on the communities and industries that depend on thriving and sustainable fisheries. Among the findings are:

- *Over 75% of the USA commercial fish catch and 80% to 90% of the recreational fish catch depend on key estuary habitat at some point in their lifecycle.* Australia's fish catch numbers have similar dependencies [e.g. DA Pollard, 1976; 1976a); 1994; RCJ Lenanton, 1974;]. .
- *Fish populations can respond quickly to habitat improvement. Rebounds in fish populations can occur within months*. Australian experience is similar – and less than weeks after a block was removed as part of a pilot Biodiversity Fund project in the Burdekin, Barramundi [*Lates calcarifer*] and Common Mullet [*Mugil cephalus*] were exploiting the repaired habitat.
- *In San Francisco Bay, restored salt marshes have improved 41 fish species including steelhead trout, Pacific herring, green sturgeon and Chinook salmon*. Many of the project proposals for NSW in this business case would presumably result in similar increased populations for Australian species such as Mulloway [*Argyrosomus japonicus*], Yellowfin Bream [*Acanthopagrus australis*], Common Mullet [*Mugil cephalus*] and Flathead [*Platycephalus fuscus*].
- *Since 2000, in Massachusetts and New York, herring, shad and sturgeon have doubled and tripled in population due to habitat restoration projects. Just two years after a single culvert was repaired connecting Bride Brook to Long Island Sound, the herring population more than tripled from 75,000 to 287,000*. This business case includes proposals to improve fish passage where possible, such as for the Murray and its Lower Lakes.
- *Within Chesapeake Bay one restoration project used oyster shell to rebuild the reef structures over a total of 86 acres. Native oysters repopulated these reefs, resulting in a 57 fold increase in the population to about 185 million oysters within 5 years*. This business case includes proposals to rebuild Oyster [*Saccrostrea commercialis*] and Mussel [*Mytilus edulis*] beds within Moreton Bay, Port Phillip Bay and the sheltered areas of the Tasmanian east coast with expected flow-on benefits to the associated multi-species fin fisheries such as the Snapper [*Chrysophrys auratus*] fishery within Port Phillip Bay.

Most importantly, with fish populations rebounding due to repaired habitat and with ongoing sustainable management these populations will be present forever, an ongoing source of food and lifestyle benefits for the Australian community.

8.5. Placing a commitment to estuary and nearshore ecosystem recovery in context

A range of catchment management and water quality improvement activities have been undertaken in all states over the last 15+ years. Water quality improvements have been substantial and the ethos of catchment management is well understood across the community. Now is the time to rethink the focus and invest in the habitats of the receiving waters benefiting from this improved water quality.

Some limited but in some cases very beneficial works have been undertaken in estuaries. This probably relates to the generally terrestrial and often private landholder engagement focus of much of the resources available for environmental repair, especially under the *Landcare* and *Caring for our Country* models. Likewise *Natural Reserves System* investments have been skewed to terrestrial landscapes.

Indeed the last time there was significant leadership from the Australian Government in estuaries was the 40% Australian Government, 40% NSW State Government and 20% local government wetland drainage and flood mitigation schemes that caused much of the problem we now seek to address.

Leadership from the Australian Government brings with it multiple benefits. Australian Government leadership and investment allows us to make the big repair investments that will deliver the 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 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 focused on sustaining the improved condition of our public estuary assets with their multiple benefits to the Australian community. Most of this ongoing investment can be achieved through smart state-level policies, and through existing revenue collection activities such as boat licences that are then re-applied to fishing benefits and community action.

The alternate case needs to be put – the dilemma of doing nothing. With no focused investment in estuary repair the prognosis for Australian estuaries and their multiple community benefits are:

- continued decline in fishery stocks with flow-on loss of jobs in regional communities and reduced seafood production
- reduced availability of 'family seafood', whether purchased or caught recreationally, especially the lower cost products that ends up on many families' dinner plates
- increasing reliance on seafood imports with implications for terms of trade, food security and food quality
- continued decline in the recreational amenity, ecology and biodiversity of these otherwise most productive of Australia's ecosystems, thereby making any repair in the longer term even more expensive;
- continued costs whether it be cleaning up massive fish kills, loss of amenity, poor water quality or algal blooms

Qualitatively, clearly there is a coherent agrument for investing in estuary repair. In times of reduced Government investment in public good natural resource outcomes a much more detailed and quantitative argument is required. Quantitative assessment in terms of when this investment would "break–even" and start delivering a profit to the Australian community was undertaken to further explore the benefits of estuary repair.

8.6. Break-even analysis – the boundary conditions and assumptions

Any investment of public resources should be well justified. Break-even analysis was applied to justify how the investment of $350M proposed in Australia-wide estuary repair would deliver medium to long-term enduring public benefits and indeed ongoing tax receipts by re-establishing a fully sustainable inshore seafood industry for Australia. A summary of this analysis extracted from the Australia-wide Report is provided here to demonstrate the highly prospective nature of investment in estuary repair.

The suite of assumptions in the break-even analysis to ensure estimated values are conservative and well below the actual likely increase in benefits were:

- **A subset of regions** - Only selected regional fisheries would be analysed and the only benefits calculated would be the projected improved returns from commercial catch. Other regions would also benefit, ensuring that even from the commercial catch perspective the analysis is an under-estimate.
- **A subset of species** - Only selected species within these regional fisheries would be analysed and again, only using projected improved returns from commercial catch. Recognising the interactions between species, other commercial catch species will also benefit. Again this ensures that even from the commercial catch perspective the analysis is extremely conservative.
- The selected fisheries analysed were:
  - A single regional fishery – Murray – Coorong, already a MSC-certified fishery in terms of methods and sustainability. Species used in this case study are juvenile and adult Mulloway [*Argyrosomus japonicus*], Black Bream [*Acanthopagrus butcheri*], Greenback Flounder [*Rhombosolea tapirina*] and Yelloweye Mullet [*Aldrichetta fosteri*].
  - A state – New South Wales, covering subtropical floodplain dominated-estuaries – essentially concentrating on the major estuaries of New South Wales while recognising the benefits will also accrue to south-east Queensland and to Gippsland Lakes. Case study species are Sydney Rock Oyster [*Saccostrea commercialis*], School Prawn [*Metapenaeus macleayi*] and Common Mullet [Mugil cephalus].

- An iconic region, the Great Barrier Reef – Tropical East Coast estuaries – essentially all the Great Barrier Reef estuaries requiring repair and using well known species of Banana Prawns [*Fenneropenaeus indicus*] and Tiger Prawns [*Penaeus esculentus and Penaeus semisulcatus].*

- **$ Value as at 2013 retail value** - $Value used was 'at retail' to capture all the benefits along the value chain from fisher to processor and market to consumer. $ values were based on values of product for 2012/13 and it was assumed these did not increase. Recognising actual increases over time of Australian seafood $ value this ensures an under-estimate of value.
- **All non-market benefits ignored** - No non-market values or even estimates of recreational fishing benefit were included in the break-even analysis so that all dollar values are deliberately less than actual. 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. This is not to deny the multiple benefits of recreational or indigenous fishing, but rather to ensure this analysis is less than likely total benefit and focuses on those aspects of a fishery that are easily valued. Likewise all the multiple non-market values of estuary repair such as biodiversity, landscape amenity, lifestyle improvements, water quality, flood control, coastal buffering, carbon sequestration and so on were not valued.
- **Biological response only starts at the end of the investment period** - Recognising that it will take some time for full ecological response, this analysis started at Year 5 of the implementation of the initiative and assumed close to full biological response by that time. As the Burdekin pilot demonstrated and as in the USA experience [Restore America's Estuaries, 2013], fish populations do respond rapidly so there will be substantial ecological benefits before that time.
- **No improvements in technology of capture** - Recognising that virtually all Australian fisheries are sustainable, current methods of catch and aquaculture practices together with any entitlement and fisheries management arrangements were assumed to be static – that is to remain as is in 2013 for the period of analysis to break even point post 2018.
- **Demand to be totally elastic and the benefits of Australian product replacing imported product not included** - that is, domestic demand expands to take up all the additional seafood productivity. With growth in the Australian population and increasing demand for seafood, it can be assumed that increase in Australian product availability would probably be matched by demand. No account was taken of the potential improvements to Australia's balance of trade of increased consumption of domestic product.
- **Market conditions as at 2013** - For simplicity in all estimates, there were no increases in value factored in nor changes such as in consumer price index.
- **Catch share to broadly stay as for 2013** - Again for simplicity, the current partitioning of stock between wild-caught professional product, recreational catch and remaining uncaught wild population was estimated. Where professional fishing effort has declined to virtually nil (e.g. Shoalhaven school prawn fishery) and the proposed productivity increases suggests a professional fishery can re-established, this proportion of catch was estimated.

These assumptions led to a deliberately very conservative break-even analysis. Even with this well less than total benefit analysis the return on investment is almost immediate – less than seven years in all cases to return the cost of investment and probably closer to three to five years maximum across the entire Australia-wide initiative as demonstrated through the three case studies.

8.7. A single regional fishery – the Coorong – Murray Mouth fishery

The Murray–Darling once nourished and supported Australia's largest estuary system of the Lower Lakes, Coorong and Murray Mouth.

During dry phases, porpoises and their prey such as Herrings and Mullets 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 will markedly improve its ecological values.

The commercial fishery, has a current annual economic value of $5.7M per annum. Estimated fishery productivity improvements of 20% across all key species could lead to comparable increases in the annual economic value (Brookes et al. in prep, 2013). These estimated values are based on South Australian market prices. For species that are sold interstate such as Mulloway and Pipi the price received is often higher. While the fishery is comparatively small, the economic and employment benefits to the regional community are substantial.

Equally importantly, 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 southeast in South Australia and all the southern estuaries of Victoria. It is likely that the Murray estuary is a key source for recruitment to the inshore and estuarine environments to the east.

Table 3: Murray – Coorong potential increases in fishery values

Target species	Historical catch (tonnes)	2011/12 catch (tonnes)	Increased productivity (%)	$ 2012	$ 2018 (2013 $ values)
Mulloway	14 – 106	64	20%	$438K	$526K
Comments: Mulloway spend much of their postlarval and juvenile phases in sheltered environments such as the Murray – Coorong estuary, proceeding to sea to spawn. Being a piscavore (consumer of other fish), mulloway productivity is an excellent indicator of overall system health. Adult Mulloway at age 3+ are caught nearshore.					
Yelloweye Mullet	110 – 346	144	20%	$585K	$702K
Comments: Yelloweye mullet are found in brackish and inshore coastal estuaries and have a preference for shallow estuaries. The mullet feed lower in the food-chain than the large piscivorous predators and while they regularly utilise estuaries during part of their life cycle they do not need access to low salinity water to complete their life cycle.					
Black Bream	1 – 47	3	20%	$37K	$44K
Comments: Black bream complete their entire life cycle within an estuary and tolerate a range of salinities from fresh to hypersaline. There appears to be a high degree of estuary fidelity. Bream are vulnerable to poor water quality and so maintaining river flows of appropriate quality is important for this fishery.					
Greenback Flounder	0 – 65	31	20%	$249K	$298K
Comments: Adult greenback flounder prefer sand silt and muddy substrates in bays, estuaries and inshore coastal waters. Adults sexually partition habitat, with females more abundant in shallow water and males more abundant in deeper water. Post-settlement and juvenile greenback 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 $.0.26K per annum **Break-even point for proposed Coorong – Murray Mouth investment estimated at $1.8M: less than 7 years**					

Pipis or Cockles 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. (Brookes et al. in prep, 2013). Congoli [*Pseudaphritis urvilli*] are an example of a major contributor to the food web and therefore feed stocks for higher order piscavores such as Mulloway. Congoli have a lifecycle that includes fresh water and marine/estuarine phases. Re-establishing connection through all the small creeks that once dominated the islands will foster a rapid increase in overall Congoli population to the benefit of the entire food chain.

Table 4: Murray – Coorong potential increases in non-costed and non-market values

Key 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 about 20% the stock available

	for recreational catch will also increase. Equally importantly to the Murray recreational fishery are the likely flow-on benefits of increased populations across south-eastern South Australia and the many estuaries 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	Seagrasses are one of the key areas of carbon sequestration. By increasing the productivity of the mid to southern Coorong seagrass extent and vigour will markedly increase.
Tourism	The Coorong region attracts a number of tourists who undertake water sports, bird watching and general leisure. Low river flows and declining lake levels in the late 2000s significantly impacted toursim in the region. 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 values.

8.8. A state, New South Wales – a key example of floodplain estuaries

Many of those that enjoy coastal and floodplain New South Wales from the Tweed to the Shoalhaven, south into Victoria such as Gippsland Lakes and Corner Inlet and north including Moreton Bay through to the Burnett, do so through their activities in the coastal zone – fishing, recreating, bird watching or just relaxing. There are also still viable professional fishing and aquacultural businesses in most major estuaries.

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 [(*Sillaginodes punctatus* and *Sillago ciliata*)] and 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 to name a few.

The repair works advocated in the Australia-wide business case are estimated to at least double fishery productivity in New South Wales (Winberg et al. in prep, 2013). Commensurate flow-on increases in both recreational and inshore professional fishing for other species are expected.

Table 5: NSW potential increases in fishery values

Target species	Historical catch (tonnes)	Current catch (tonnes)	Increased productivity	$M 2013	$M 2018 (2013 $ values)
Sydney Rock Oyster / Pacific Oyster	140 000 bags Sydney Rock Oyster only	39 475 bags Sydney Rock Oysters 2720 bags Pacific Oysters	Return to at least 1970 production levels for Sydney Rock Oyster; Pacific Oysters to at least retain current production levels	$30.3M	$100.4M (assuming increaases in only Sydney Rock Oyster and Pacific Oyster retains existing production levels)
Comments: Oysters are an integrator of overall estuary condition and most importantly the net primary productivity within that estuary. Sydney Rock Oyster aquaculture production crashed from a peak in the 1970s due to a range of catchment stressors that include acid soil and anoxic runoff, poor sewage management systems, harmful algae blooms and major QX disease outbreaks. The QX resistant and more rapidly growing Pacific Oyster has been introduced as a replacement in many estuaries, although this species has also now been affected by catastrophic disease outbreaks. Data sources from NSW DPI (2013). Aquaculture Production Report 2011–2012. NSW Department of Primary Industries. Port Stephens Fisheries Institute.					
Mullet (*Mugil cephalus* & *Myxus elongatus*)	<3000 tons 200 tons	>5000 tons 120 tons	Return to at least mid-1990s levels	$7.6M	$50M
Comments: 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, to some degree underrated by the consumer marketplace. However it is the biggest biomass of commercial catch in NSW and provides high value export roe products, as well as business operations for Aboriginal Australians. It is a very sustainable species with high fecundity, however in the last decade the average catches have dropped by close to 50% compared to prior long-term stable catches. Considering the high fecundity a lack of reproductive output is not considered to be a significant contributor to this reduction. The evidence for recent disease outbreaks of Red Spot lesions and reduced populations suggests that flood plain management systems as well as artificial flow regulation contribute to this decline. Mullet generally spawn inshore at age 3 onwards with larvae recruiting to estuaries and particularly fresh to brackish wetlands. Repairing the previously drained and barraged floodplain wetlands, as is the proposed focus of much of the eastern Australian investment will lead to markedly increased populations of mullet and will also alleviate the current fish diseases of red spot. Mullet are closely linked to the net primary productivity of the estuaries and to fresh to brackish wetlands being low in the estuary food chain. This is expected to lead to comparatively rapid increases in their population.					
School Prawn	>1000 tons	674 tons	Return to at least mid-1980s levels	$5.8M	$12M
Comments: School Prawn *(Metapenaeus macleayi)* are highly fecund annual stock with close correlations between stock and climate – wetter years with more brackish estuaries and more connection between estuary and wetlands leading to higher populations. School prawn spawn close inshore with almost immediate recruitment to estuaries and provide the fifth highest biomass of commercial fish catches in NSW 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 is 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 extremely conservative.					
Total estimated productivity value increase for these selected species post 2018: at least $119M per annum **Break-even point for proposed New South Wales floodplains investment: less than 3 years**					

Other key 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.

Table 6: NSW potential increases in non-costed and non-market values

Key non-costed and non-market benefits	
Recreational fishing	Yellowfin Bream, Dusky Flathead, Sand Whiting, Luderick, Sea and River Garfish, Mulloway, Mud and to a lesser degree Blue Swimmer Crabs and School Prawns are all target species. With estimates of productivity increases as outlined above the stock available for recreational catch will markedly increase.
Reduced likelihood of anoxic events and acidic leachate causing fish productivity / biodiversity losses and diseases	The major thrust of much of the 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 cormorants such as brolgas, darter, little cormorant, ibis and egrets.
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 about 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, agriculture and fisheries.

8.9. An iconic region – the Great Barrier Reef catchments

The Great Barrier Reef is more than just the coral reefs – seagrasses, mangroves, salt marshes and brackish to freshwater wetlands are essential parts of the reef ecology.

For example, Red Emperor spends its nursery phase within nearshore and estuarine environments. Without a healthy nursery there will be fewer adult fish with flow-on implications to coral ecosystems, commercial and recreational fishing, and diving and snorkelling experiences. The Great Barrier Reef tourist industry is estimated at between $4B and $5B per annum (GBRMPA 2009).

Three key species that have a very clear estuary dependence and have lost habitat and therefore have had productivity decreases and with repair, have potential productivity increases are Barramundi, and Banana and Tiger Prawns.

Barramundi post larvae and juvenile phases up to at least three years of age feed and grow within estuarine to fresh environments. Spawning near estuary mouths then leads to recruitment of juveniles back into the estuarine and freshwater habitats. Because Barramundi exploit entire river systems, increase in Barramundi productivity would be a broad indicator of connectivity and associated increased area of improved habitat. For example the work on the Fitzroy now funded under Reef Rescue II to provide passage through wetlands to the upper Fitzroy around the main weir just above Rockhampton will ensure Barramundi have access to at least another 120 km of main river channel – without counting side channels, contributing rivers and creeks. However actual increase in population of Barramundi let alone what proportion will be caught in the commercial fishery, or in the recreational fishery or will remain wild is not easy to predict. No knowledge is available of carrying capacity and how it might vary with instream water quality and food stock availability. There are as yet no reputable scientific predictions of productivity increases per unit area of repaired waterway or wetland habitat. Therefore no estimate of dollar return can be made with any degree of accuracy.

Banana Prawns spend their larval, post larval and juvenile phases in estuarine environments, especially mangroves and salt marshes, with sub-adults then exploiting seagrass and both

sandy and muddy bottom environments. As with other crustacea, the 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 instream barriers.

Tiger Prawns spend their larval, post-larval and juvenile phases in lower estuarine environments, especially seagrasses. Increased productivity of Tiger Prawns follows from increased health and vigour of seagrass beds and thus water quality/reduced turbidity.

The science has yet to be done to fully understand reductions in productivity of Banana and Tiger Prawns with reduction in habitat availability. Further the historical data on catch is very incomplete, let alone any useful estimates of catch as a proportion of total stock available. Many of the changes to habitat for both these prawn species were well underway by the late 1950s and 1960s. Excessive turbidity and the loss of seagrasses accompanied all grazing, agriculture and roading development. 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 about 1995 onwards because of the impacts on prawn stocks and fisheries generally.

The actual decline in total population from 1950s onwards is simply impossible to predict without further science that provides estimates of carrying capacity for the various components of habitat and their interactions. This information could then be used to trace changing productivity accompanying the losses of habitat through until the present day to determine a changed carrying capacity and thence projected reduced total biomass.

In addition to changed habitat availability there have been significant changes in fisheries effort and fisheries management. This includes improvements in the methods of catch and gear, 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. This adds to the complexity of any estimates of reductions in prawn productivity.

Nevertheless the data on tonnage production that is available from 1990 to 2009 suggests a total commercial catch decline from about 5500 tonnes to about 4000 tonnes over this period. Disentangling habitat causes from other causes is impossible. At the same time, even with the various restrictions on catch and entitlement there is certainly no indication that the wild uncaught stock has increased as a proportion of the total annual population.

Even if the most repair we can achieve is such as returning habitat available and improved connectivity to the level of that of about 1990 and assuming 50% of the improvements is in the more valuable Tiger Prawn population then the approximate increased value of commercial prawn product would exceed $45M per annum at today's prices. This sugests a break-even point for the proposed Great Barrier Reef region investment of less than two years.

No estimates can readily be made for the many other species that would benefit. In terms of other key non-costed and non-market benefits the following summarises some of the key benefits.

Table 7: Great Barrier Reef catchments potential increases in non-costed and non-market values

Key non-costed and non-market benefits	
Recreational fishing	Recreational fishers target Mangrove Jack and Barramundi from fresh to brackish to estuarine to nearshore environments. Red Emperor, Estuary Cod and Coral Trout along with the many other coral reef species that spend the early life phases inshore are targeted whenever the weather is benign enough for small boat travel to the reef proper. Many other species such as the pelagics (e.g. Spanish Mackerel) are also targeted. Indeed virtually all recreational species with the exceptions of Tuna and Billfish rely on estuarine and nearshore environments so that any improvements in productivity will be reflected in their catch rates.
Coastal biodiversity	Iconic species such as Turtles and Dugongs will benefit from repair as indeed will the entire marine ecosystem towards a healthier total reef system. Improving the health of estuarine and inshore ecosystems is also expected to be addressing some of the core causes of Crown of Thorns outbreaks – far more effective and sustainable than harvesting mature

	Crown of Thorns.
Great Barrier Reef World Heritage standing and values	UNESCO has recognised that the Great Barrier Reef is comprised of a linked set of marine and estuarine ecosystems. This initiative focuses on the most degraded component of this system – the estuaries and wetlands.
Carbon sequestration	Mangroves, salt marshes and seagrasses comprise about 39% of Australia's carbon sequestration and have the greatest potential for carbon storage of any ecosystem on the planet, many times greater than tropical rain forests
Tourism	There are many estuary/ecotourism companies that take nature appreciation and fishing tours within the reef's coastal landscapes.
Indigenous	Indigenous ecotourism ventures such as Mungalla focus on coastal wetlands. Major indigenous settlements on the coast (e.g. Yarrabah) are based largely around coastal resources.

9. FURTHER DEVELOPMENT

Work towards advocating leadership and Australian Government investment will continue. There are likely to be various opportunities as any in-coming Government seeks to re-think how best to invest in natural resources and environmental initiatives with or without the revenue currently available through the Carbon Tax and Biodiversity Fund.

From a knowledge development perspective, following are the two key areas of further development most pertinent to Fisheries Research and Development Corporation –

- priorities for funding RD&E ; and
- a changed paradigm shift to what compromises a sustainable fishery to include ecosystem health and habitat availability and therefore how best to manage most Australian fisheries with their dependence on estuarine and nearshore ecosystems.

9.1. Underpinning repair action with research

Linking knowledge to works is essential if Australia is to maximise the returns on the investment in repairing Australia's estuaries. Following are a broad set of potential topics that would benefit from further research. Subject to funding availability, many of these priority areas could proceed immediately and would contribute much needed knowledge towards rational and prioritised repair of inshore fisheries habitat.

9.1.1 Ecosystem ecology and responses

Estuary event management for landscape optimisation - 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. Clarence) and a southern NSW estuary (e.g. Shoalhaven) to understand how best to optimise floodplain management across multiple land uses and objectives. For this topic good hydrographical models, as already available for these three estuaries, are needed as a base. The research would establish how best to utilise wetlands, levees, estuary, dredging, flood infrastructure and so on for the multiple objectives of fisheries, biodiversity, water quality, flood protection and agriculture.

Output – Multi-criteria analysis method for optimising outcomes for the landscape, both human and ecological benefits.

Tidal hydrology and repair of estuary morphology - Sedimentation from catchment loads and confining infrastructure such as training walls, crossings and causeways has changed estuary tidal hydrodynamics and therefore net primary productivity. Repair dredging (e.g. Manning entrance plus many within-estuary sites), changes to historic training walls (e.g. Middle Wall, Clarence; Googleys Lagoon, Camden Haven) and changes to causeways and sedimentation patterns (e.g. Clarence – Shallow Channel, Romiaka Channel, Oyster Channel and Palmers Channel feeding Lake Wooloweyah) are all examples of interventions worth exploring to understand how net primary productivity can be optimised. In thinking through improved tidal ventilation it will also be essential to analyse how such works would improve wetland productivity and provide repaired habitat for seagrass re-establishment.

Output – design guidelines for repair of selected estuaries that also provide a model set of criteria for application to other estuaries.

What is the estuary productivity and how should this be used to improve fisheries management, including resource sharing? - Recreational effort is increasing inshore, particularly around major urban centres. Variable climate plays out in fish population fluctuations. If the productivity across species and including species interactions is known then the impacts of major development on habitat will also be better defined and may lead to better development decisions. Linking fishing effort to stock available should also make fisheries more profitable.

Output – changed paradigms for effort, resource sharing and development approvals.

Priority locations – do they exist for Australian inshore species? - New Zealand research suggests some species may have priority location nursery habitats for up to 80% of their stock

in a particular estuary, later dispersing widely. Does this occur in Australia such as the Murray for the estuarine and nearshore ecosystems to the east in both South Australia and Victoria, and if so, how would we best protect or rehabilitate these important areas.

Output – better understanding of species locational preferences and a basis for improved species population management.

The freshwater–brackish–saline interface and net primary productivity - Brackish, intermixed systems are known to be the most productive of all the world's ecosystems. Unfortunately accompanying land use changes is modifying catchment hydrographs, with developed catchments characterised by more peakier runoff flows with much sharper recession curves. This markedly reduces the spatial and temporal extent of brackish, intermixed systems. The challenge is how can we through land use management and other interventions such as reducing the rapid drainage of wetlands; change catchment hydrographs back towards a more dampened sinusoidal long recession curve mixed system?

Output – better understanding of catchment hydrology links to net primary productivity, especially important for more regulated estuary systems.

Larval recruitment – has it been influenced by training walls and other structures? - Major wave-dominated estuaries pre-settlement were a maze of entrance sand spits. Much of the spawning (Mullet, Bream, Whiting, School Prawn, Eastern King Prawn, Barramundi) presumably occurred here with a high probability of rapid larval recruitment back into the estuary. Where do these species spawn now and can any manipulation of estuarine entrance areas assist higher recruitment back into estuaries?

Output – Better understanding of larval dispersal and opportunities to enhance recruitment to nursery areas.

9.1.2 Human interactions with estuarine ecosystems

Mixing the public and private benefits of estuary and wetland conservation – should fishers and the community that consume seafood pay farmers for habitat repair on private lands? - Much of the challenge with estuary management lies in the public benefits that estuaries provide compared to the private benefits that come from land development. On Australia's floodplains, development has been for private benefit, especially agriculture and grazing with increasingly urban development at the expense of the more public benefits of biodiversity, water quality and fisheries. Fisheries can lead to private benefit when professionally harvested for food or caught as part of recreation and lifestyle. Fisheries and agriculture both provide national benefit such as in food security. How can these various benefit streams be bought together to ensure ongoing investment in estuary repair and management?

Output – Exploration of the opportunities for cross-subsidisation 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 input controls such as fishing gear, size of boat, number of nets, number of dories and so on. Fisheries management is gradually moving towards output controls based on the presumed, sometimes modelled and monitored, size of the population available for catch and therefore some estimate of 'sustainable economic yield'. Yet with much of all professional catch Australia-wide having an estuary-dependent phase in their lifecycle, these estimates of sustainable yield should also be taking account of estuary condition, its improvement or decline in condition. If we choose to repair estuaries we can increase sustainable yield, or as is currently the case, do nothing, so that sustainable yield will inevitably continue to decline.

Output – Linking habitat condition to sustainable economic yield should give further impetus to better manage our estuarine and nearshore habitats, or at least foster understanding that further degradation has a direct impact on seafood security.

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. Galvanising this sector of the population to a lead role in estuary management, repair and protection will reduce the need for ongoing government investment.

Output – Schemes and engagement models in place overseas could be explored to provide a toolbag of possible schemes for Australia for the various recreational fisher groups to consider.

Understanding and valuing the multiple outcomes that accrue from good estuary management - Multiple benefits besides fishery productivity accrue from good estuary management including flood control, coastal biodiversity, extreme climate event buffering, water quality, landscape and general public amenity and carbon mitigation. Most of these are public benefits. Understanding these and their overall value can influence public investment and community behaviour.

Output – A better understanding of the role and benefits of improved estuary management.

Policy, legislation and regulations – what works? - Various states have differing levels of environmental policy pertaining to estuaries and wetlands. Are there particular policy, legislative and regulatory approaches that deliver more cost-effective and efficient outcomes for estuary management than others? What are the key criteria that might need to be embedded within all state approaches to maximise sustainable fisheries productivity?

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 in all states.

Resource sharing within repaired estuarine environments - Estuaries by virtue of their location and being the more sheltered easily accessible waters are generally areas of high recreational effort. Professional catch also has a high estuarine dependence. Re-building such as mussel or oyster reefs in Port Phillip or Moreton Bay is likely to lead to increased commercial and recreational pressure. How can any increases in productivity brought about by habitat repair be best shared? If recreational fishing was to say 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 following habitat repair and how any particular scenarios in resource sharing might lead to increased investment in estuary repair.

9.2. Rethinking the Fisheries Management Paradigm

This project has also revealed a gap in our knowledge that requires further investigation. Under classic fisheries management theory and as demonstrated around the world, fisheries typically move from “nascent” to “developed” and then to a “sustainably developed” phase (with Maximum Sustainable Yield as a goal). A more recent trend in fisheries management for the target species is towards “economically sustainable yield” (Maximum Economic Yield). In tracking this evolution, a commonly used metric is a measure of Catch per Unit Effort (CPUE), with stable CPUE regarded as evidence of “sustainable” fishing effort.

Such approaches are less than optimum when total population declines and effort reduces such that local CPUE remains constant while total population declines. This may also occur when fishing effort moves around to maintain CPUE (e.g. abalone), Less recognised are changes outside the mandate of the fisheries management body that also impact on the exploited population such as reduced habitat or poor water quality causing reduced productivity.

For a range of coastal fisheries, fishing effort and catch may not be the major stressor. Loss of physical habitat and declining water quality is for most inshore fisheries the major stressor on productivity. This suggests the need for research towards a change in paradigm for fisheries management towards stock productivity as the major metric for management. Some fisheries research is recognising changes in marine productivity that might influence stock size and hence sustainable fishing limits (e.g. Wayte 2013), but few assessments consider non-fishing impacts such as habitat loss when establishing sustainable fishing targets.

To underpin sustainable fishing in the face of increasing coastal and population pressures, it is suggested that there is a need to assess productivity potential based on the quality and extent of available habitat and to be able to track fishery productivity in addition to fishing effort. Where fisheries could be improved if habitat were repaired new thinking is needed to identify ways to resource investment in habitat repair as another important tool in fisheries management.

10. CONCLUSIONS

The following conclusions demonstrate that this suite of projects, being 4 pilot areas for repair and two business cases have achieved the objectives of this project –

- repairing estuarine ecosystems while challenging and often requiring a case by case approach with the consent of local communities and a plethora of approval processes, can rapidly yield fisheries productivity benefits with flow on outcomes to the Australian economy and lifestyle

- repairing estuarine ecosystems, while largely ignored to date in our investment in repair of Australia's ecosystems, will not only yield substantial benefits to the Australian economy and lifestyle but will break even in investment with direct $ returns to the Australian economy within comparatively short time frames.

The more traditional investment in ecosystem repair such as wildlife corridors or terrestrial biodiversity repair that has to date dominated much of the *Natural Heritage Trust / Caring for Our Country* investment streams is often focused on intrinsic environmental value. Repairing fisheries habitat provide dual benefits of almost immediate $ returns as well as high intrinsic environmental value.

The two business cases have detailed the priority repair opportunities across Australia. Certainly there is much that could be done if Australia was to invest in these public assets. As to why this very attractive investment opportunity has to date 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". Or in the more Australian vernacular, quoting a professional fishing colleague from the mid 1970s– *Rivers – they won't fix them unless they catch on fire ...* '.

The two business cases provide a set of priority activities within a fully structured framework from policy to works, monitoring, communication, research and reporting. So far, the works component of the Great Barrier Reef business case is receiving investment through the "Systems Repair" component of Reef Rescue II. It remains for professional, indigenous and recreational fishers together with the broader community across Australia to collectively and collaboratively advocate for strategic investment in repair for the remainder of Australia.

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12. DETAILS ON ACCOMPANYING REPORTS

Revitalising Australia's Estuaries – Australia-wide

The business case for repairing coastal ecosystems to improve fisheries productivity, water quality, catchment hydrology, coastal biodiversity, flood control, carbon sequestration and foreshore buffering; covers priority opportunities for all of Australia, state by state excepting for the Great Barrier Reef catchments; ISBN: 978-0-9923366-0-8

Revitalising Great Barrier Reef estuaries and coastal wetlands -

The business case for repairing Great Barrier Reef coastal ecosystems to improve fisheries productivity, water quality, catchment hydrology, coastal biodiversity, flood control, carbon sequestration and foreshore buffering; covers the GBR catchments in natural resource management regions as an input to Reef Rescue II; ISBN: 978-0-9923366-1-5

Revitalising Australia's Estuaries, Broadwater Creek, Clarence Estuary Review of Environmental Factors

Provides a summary of the environmental factors to be considered and addressed in repairing Broadwater Creek; Clarence Valley Council

Revitalising Australia's Estuaries, Pilot Project, Burdekin floodplain - wetlands –

Project reports, November 2012 & July 2013 from NQ Dry Tropics NRM group detailing the work done to repair connectivity and thence re-establish fisheries habitat;

Revitalising Australia's Estuaries, Pilot Project, Pioneer estuary -

Project report detailing the work done to repair connectivity and fisheries habitat, Reef Catchments NRM group; ISBN: 978-0-9923366-4-6

Revitalising Australia's Estuaries, Pilot Project, Richmond estuary –

Project report detailing Empire Vale Pilot & Rocky Mouth Creek Emergency Fish Escape in the Richmond River catchment, Richmond River County Council ISBN: 978-0-9923366-3-9

13. KEY CONTRIBUTORS

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APPENDIX 1: INTELLECTUAL PROPERTY

The results of this study will be published so that they are available for use by fisheries, scientists and fisheries and environmental managers but will have no direct commercialisation potential.