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Committee Secretary
Senate Environment and Communications References Committee
PO Box 6100
Parliament House
Canberra ACT 2600

Current and Future Impacts of Climate Change on Marine fisheries and Biodiversity

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Senate Inquiry – Current and Future Impacts of Climate Change on Marine Fisheries and Biodiversity

Executive summary

Australia's oceans generate considerable economic wealth through fisheries, aquaculture, tourism, oil and natural gas, and transport. Marine ecosystems provide irreplaceable services including oxygen production, nutrient recycling and climate regulation.

Climate change is already impacting on estuarine and marine fisheries and biodiversity with extreme climate variability events well documented.

Adaptation and flexibility are key – Australia's policy and management frameworks are well placed to respond because they are already adaptive and flexible.

The key principles in Australia's strategic approach to marine fisheries and biodiversity management including our changing climate are:

Widespread recognition of a changing marine environment:

The fishing industry, management and science all recognise that Australia's oceans; their physical characteristics, marine biodiversity and fisheries are already experiencing and responding to a changing and more variable climate. This flow-on in climate, ecological and economic change is occurring at a far more rapid rate than that occurring terrestrially. Adapting to this changing climate is essential if Australia is to maintain, build upon and profit from the wealth of goods and services provided by our marine environment.

Continuing to ensure sustainability in our marine management:

Australia has an outstanding international record of fisheries and aquaculture management for sustainability underpinned by science enquiry. Climate change science linked with broader marine and aquatic ecosystem science is a key underpinning to this Australian leadership in marine sustainability.

Adaptation is key:

Australia's fisheries management is already based on the principles of adaptive and flexible responses – changes in fish stocks (e.g. abundance, natural mortality, spatial density,) is mainstreamed into scientific assessments of Total Allowable Catch that inform Harvest Strategies and Management Plans. Responding to a changing climate is best undertaken as part of this science-based adaptive response.

Climate impacts must be included as part of an adaptive management response:

There is a large body of science on changing climate both specific to Australia and transferable from overseas that is relevant to fisheries management. Australia's fisheries management agencies are progressively applying this science as they mainstream climate issues when managing fish stocks.

Ensuring a strong legacy for our science investments:

Australia has a well-established system of data collection to support management:

- wild fisheries – e.g. regular stock abundance assessments; surveys to predict recruitment; catch, sales and effort data
- aquaculture – e.g. marine based aquaculture industries all have comprehensive data and environmental monitoring programs
- research findings – e.g. all FRDC contracts require data sets to be specified and stored readily available for other users
- ongoing data availability – e.g. the Integrated Marine Observing System (IMOS) provides an Australia-wide repository for data collected during science inquiry.

Building an enduring science-based marine policy framework for Australia:

Expediting the inclusion of climate issues within Australia's marine adaptive management framework will be done in three broad phases – preconditioning, future proofing and transformation / opportunity. The task ahead is elaborated in Section 3 that follows the specific responses to each Term of Reference.

Focused and enabling investment:

All investment must be timely, responsive to need and at a quantum that matches the task. Two areas appear to be particularly prospective for the five-year period 2017 to 2022:

i. enhancing the science – manager interface and
ii. repairing ecological resilience.

These prospective investments are outlined in Section 3c.

1 – Introduction

On 14 September 2016, the Senate referred the following matter to the Environment and Communications References Committee for inquiry and report by 30 June 2017:

Inquiry into the impacts of climate change on marine fisheries and biodiversity

Terms of reference

On 14 September 2016, the Senate referred the following matter to the Environment and Communications References Committee for inquiry and report by 30 June 2017:

The current and future impacts of climate change on marine fisheries and biodiversity, including:

(a) recent and projected changes in ocean temperatures, currents and chemistry associated with climate change;

(b) recent and projected changes in fish stocks, marine biodiversity and marine ecosystems associated with climate change;

(c) recent and projected changes in marine pest and diseases associated with climate change;

(d) the impact of these changes on commercial fishing and aquaculture, including associated business activity and employment;

(e) the impact of these changes on recreational fishing;

(f) the adequacy of current quota-setting and access rights provisions and processes given current and projected climate change impacts;

(g) the adequacy of current and proposed marine biodiversity protections given current and projected climate change impacts;

(h) the adequacy of biosecurity measures and monitoring systems given current and projected climate change impacts; and

(i) any other related matters.

Much of Australia's climate science investment builds on the *National Climate Resilience and Adaptation Strategy* (2015). This Strategy specifically affirmed a set of principles to guide effective adaptation practice and resilience building being:

i. shared responsibility
ii. factoring climate risks into decision making
iii. an evidence-based, risk management approach
iv. helping the vulnerable
v. collaborative, value-based choices
vi. revisiting decisions and outcomes over time.

This submission to the 2016 Senate Inquiry builds on investment to date in research and management support for fishing and aquaculture. The submission includes references to many activities undertaken over the previous five years including a major R&D program on climate change adaptation for fisheries and marine biodiversity undertaken through the Fisheries Research and Development Corporation (FRDC) and its partners. The submission also refers to research investment currently underway. Key partners for FRDC include Australian, State and Territory Governments, the wild harvest, recreational fishing and aquaculture industries and Australia's leading research providers – universities, CSIRO and AIMS. FRDC's submission should be read in conjunction with these submissions and particularly those from CSIRO and the University of Tasmania.

Sections 6 (FRDC research completed) and 7 (FRDC research underway) demonstrate the scope and breadth of investment to date.

2 – Responses to the specific Terms of Reference

a) recent and projected changes in ocean temperatures, currents and chemistry associated with climate change;

There has been much done to monitor and predict changes in our ocean temperatures and currents and to a lesser degree ocean chemistry such as changing pH. Changing conditions on both the east and west coasts of Australia are well documented and reported on, via science project reports and published papers. The CSIRO submission will provide substantial detail on findings to date. Key points include:

- ocean temperature is the best understood and best modelled of the three main physical attributes – temperature, currents and chemistry
- ocean currents require ongoing monitoring and then coupled with predictive modelling will provide information on spatial and temporal changes, essential inputs for multiple applications and decision support
- ocean chemistry is comparatively the less understood of the three attributes
- there will always be levels of uncertainty due to the confounding nature of separating climate variability from climate change
- changing ocean temperatures and currents are impacting upon our fisheries and marine biodiversity
- south-east Australia is a climate warming hotspot and extreme heat wave events occur all around Australia
- the extreme sea surface temperatures are projected to increase in the Tasman Sea with a greater than 50% chance that the annual maximum sea surface temperatures will increase by at least 2^{o}C in the south-east hotspot
- heat wave conditions such as those experienced in recent years along the Western Australian coast have had substantial impact on both fisheries and biodiversity, and the frequency and impact of such extreme events is rising
- there is an ongoing need for continued science investment
  - e.g. the deployment of sensor arrays from RV Investigator
  - e.g. the AIMS Sea Simulator or *SeaSim* seeking to understand the implications of changing pH
- applications arising from knowledge and monitoring of our oceans are multiple; the best recent example is the substantial improvements in forecast skill under the Bureau of Meteorology's dynamic modelling and the resulting seven-day forecasts for Australia.

In brief:
There have been substantial changes in ocean temperatures, currents and chemistry. These are predicted to continue. Ongoing investment in both monitoring and research is essential.

Case study: Ocean Monitoring with Ships and Buoys

Research agencies around Australia play a role in collecting information on the state of the ocean. As one example, the CSIRO is charged with delivering globally consistent and authoritative information and services that enable Australian governments, industries and communities to predict and respond to weather, climate and ocean variability and change, and extreme events. This information has been critical to understand how the changing ocean affects marine fisheries.

RV Investigator is Australia's state-of-the-art marine research vessel, supporting atmospheric, oceanographic and biological research from the tropical north to the Antarctic ice-edge. This platform is helping Australian scientists to map the sea floor, study marine life to learn more about where fish live, eat and breed in order to better manage our fisheries, and collect water samples to help understand where ocean currents travel and to monitor changes in deep ocean temperatures.

Improving our understanding of ocean processes will enable us to forecast climate and ocean conditions more accurately. CSIRO is also part of a major international effort to improve understanding of the ocean through the use of a global array of robotic floats, known as Argo floats. The Argo floats are a network of 3600 free-floating sensors, operating in open ocean areas that provide real-time data on ocean temperature and salinity. The floats drift at depths of between 1 and 2 km, before ascending to the surface every ten days, measuring temperature and salinity as they rise. The data are then transmitted to satellites, before the float dives and starts a new cycle. Argo robotic floats can be deployed from research or commercial ships, and also from aircraft. They are the only means to collect the subsurface observations needed to provide year-round, near real-time information on ocean conditions.

New 'Bio Argo' floats, launched in mid 2014, will enhance the already successful Argo float technology to measure large-scale changes in the chemistry and biology of marine ecosystems below the Indian Ocean's surface. The 'Bio Argo' floats will include additional sensors for dissolved oxygen, nitrate, chlorophyll, dissolved organic matter, and particle scattering. They will target specific gaps in our understanding of Indian Ocean ecosystems of immediate concern to Australia, such as the waters of north Western Australia.

Collectively, these and other monitoring efforts provide the backbone of scientific understanding regarding the impacts of climate change on marine life.

b) recent and projected changes in fish stocks, marine biodiversity and marine ecosystems associated with climate change;

Changes in fish stocks, marine biodiversity and marine ecosystems that are attributable to climate change are starting to be better understood and documented. Further changes are expected and indeed many of our current models of change may be conservative when compared to the actual changes being experienced. These changes in fish stocks, marine biodiversity and marine ecosystems include:

- along the mid to southern Australian West coast, key fisheries such as Western Rock Lobster (*Panulirus cygnus*) and Abalone (*Haliotis spp*) are already being affected in both spatial extent and total population; the recent 'heat wave' conditions for the Indian Ocean Current were well documented and the impacts were substantial – e.g. massive mortality for sessile fauna such as 99% Roei Abalone (*Haliotis roei*) and major reductions in recruitment of Scallops (*Amusium balloti*), Western King (*Penaeus latisulcatus*) and Brown Tiger (*P.esculentus*) Prawns. Management responded imposing effort reductions and both spatial and temporal closures.
- along the Australian East coast there have been transitions south of mobile species and changes to marine habitat – e.g. Mahi-Mahi (*Coryphaena hippurus*) caught recreationally in Tasmania; range extensions of Long-Spined Sea Urchins (Centrostephanus rodgersii), and consequent changes from kelp-dominated habitat to 'urchin barrens' with flow on ecosystem changes such as to Southern Rock Lobster (*Jasus edwardsii*) populations
- range expansion and / or the drift south of many recreational target species (citizen science techniques such as RedMap have played a substantial role in fostering fisher awareness of the changing conditions)
- modelled predictions that the Southern Rock Lobster will be replaced by Eastern Rock Lobster [*Sagmariasus verreauxi*] along the Tasmanian east coast

Modelling and predicting how our ecosystems will respond is an ongoing valuable science input to management; e.g. CSIRO *Atlantis* modelling scenarios inform management in real time and explore 'work arounds' for fisheries management teams to contemplate and where appropriate incorporate in revised and more flexible management arrangements

The abundance of stocks for inshore fisheries are particularly susceptible to varying climate, especially periods of high rainfall / floods and drought; it is difficult to disentangle shifts and variation in abundance due to climate variability from shifts due to a changing climate. A key strategy to ensure inshore fishery resilience is to reduce, as much as possible, other shocks on their populations such as by improving water quality and repairing habitat.

In brief:
Substantial changes are underway; our science is endeavoring to both monitor and predict these changes and to provide scenarios for management to evaluate. Early detection of changes in abundance, an understanding of the causes of change coupled with flexible harvest strategies will facilitate rapid management responses to ensure Australia continues its world leading record in wild harvest fisheries sustainability.

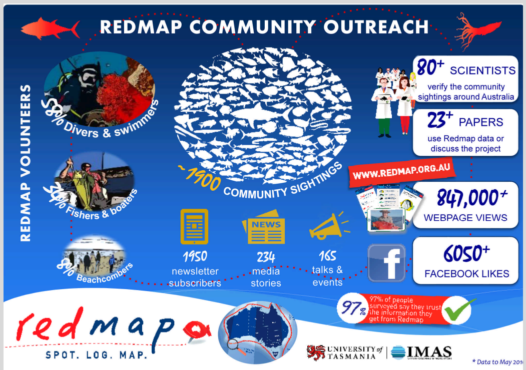
Case study: Redmap / role in awareness and charting changes

Redmap (Range Extension Database & Mapping Project, redmap.org.au) is an Australia wide citizen scientist project that invites fishers, divers, boaters and naturalists to submit photographs of species that they observe outside the expected distribution for that particular species, a coral trout in Victoria for example. The project has two key aims:

1. to provide ecological information on which species may be shifting further south as our waters warm, and

2. to increase awareness of marine climate change within the public.

The identification of potential 'range shifts' is critical for understanding the impact of climate change on ecosystems and on our ability to be able to respond effectively (Madin et al. 2012).



Redmap provides an effective tool for communicating scientific issues and involving public participation in data collection; and through this, the public are *actively engaged* in the generation of knowledge about how marine systems are responding to short and long term environmental patterns and changes. Redmap has so far provided valuable data contributions to over a dozen scientific publications that have helped understand climate change impacts in marine systems (e.g. Robinson et al. 2015, Johnson et al. 2011, Last et al. 2011, Ramos et al. 2014) – all demonstrating that many species are shifting further south along Australia's coastline. Research has also shown that Redmap data is *trusted* by the public, and that participation in Redmap does indeed successfully *build awareness and understanding* of marine climate change in the community (Bannon 2016).

Redmap is a powerful yet simple and positive way to engage everyday people on issues of biodiversity and climate change, whilst also providing opportunities to learn about scientific principles related to species biology and ecology, oceanography, marine habitats and many other scientific concepts.

Tom Srodzinski with his first yellowtail kingfish (*Seriola lalandi*) caught from the Tasman Peninsula. Photo credit: Jonah Yick

Red emperor (*Lutjanus sebae*) caught off Green Head, WA – 50m of water, 16km offshore. Photo credit: James Florisson

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c) recent and projected changes in marine pest and diseases associated with climate change;

Key points include:

- elevated water temperatures can act as a stressor impacting the immune responses of all cool water aquatic animals such as Abalone, Atlantic Salmon and Pacific Oysters, potentially increasing their susceptibility to bacterial, viral, fungal and parasitic infections
- stressors can lead to major impacts on wild harvest fisheries and aquaculture – e.g. major floodplain wetland drainage and the accompanying increase of acidic runoff led to the contraction in the range of Sydney Rock Oyster (*Saccostrea glomerata*) aquaculture in south-east Queensland and NSW estuaries, with debilitating diseases such as QX accompanying these acidic runoff events
- disentangling causal relationships for disease outbreaks is challenging and will always require ongoing work
- harmful algal bloom (HAB) outbreaks such as those resulting from the dinoflagellate *Alexandrium tamarense* on the East Coast of Tasmania are becoming more commonplace. These blooms increase the risk of Paralytic Shellfish Poisoning (PST) and have resulted in lengthy fisheries closures with devastating consequences to shellfish and other sectors. There are increasing questions world-wide on the interactions between HABs tides and a changing climate.

Examples of current investments include:

- *Sens T* – a project to detect changing temperatures specifically for the oyster industry.
- *Pacific Oyster Mortality Syndrome* (POMS) – especially research to enhance industry practices. POMS only causes problems in summer. Tasmanian oyster farms are trialling 'window farming' – farming oysters in infected areas over the cooler months and harvesting before warmer water temperatures raise the risk of significant losses. Extended periods of warm water will reduce the viability of this practice.
- Abalone farms – these are highly susceptible to elevated temperatures, losing stock to heat stress during periods of high temperatures. The only method to alleviate this problem is to increase water flow through rearing systems, increasing operational costs.

In brief:

At the very least, general statements apply – a changing climate with changing ocean chemistry, temperature and increased frequency of extreme events will add stress to our estuarine, nearshore and marine biota. Susceptibility to diseases will often increase. Understanding diseases, the vectors of transmission and developing management practices are all generic strategies for disease control and specifically also apply for diseases related to a changing climate.

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d) the impact of these changes on commercial fishing and aquaculture, including associated business activity and employment;

Key points include:

- transitions to 'smarter management systems' for harvest fisheries that incorporate all relevant factors, including a changing climate will progressively be implemented by Australia's fishing management agencies and will build on available science
  - e.g. improved management arrangements, Western Rock Lobster
  - e.g. continuing improvements in management arrangements for Southern and Eastern Scalefish and Shark Fishery (Commonwealth Trawl Sector)
  - e.g. recent opportunity for higher catches in Yellowfin Whiting (*Sillago schomburgkii*) apparently due to warmer water, Peel Harvey and Mandurah region, WA has led to adaptation in fisheries management
- a changing climate is one of the many factors that managers consider as fisheries transition towards more adaptive management arrangements
  - e.g. multi-entitlement systems
  - e.g. flexible quota, reviewed annually and set based on stock information and bio-economic models
- inshore harvest and recreational fisheries are likely to be the most fluctuating of all fisheries in available biomass; this is because runoff / floods and drought are key drivers of biomass for all inshore wild harvest and recreational fisheries:
  - e.g. Banana Prawn (*Fenneropenaeus merguiensis*, *F. indicus*) fisheries
  - e.g. Barramundi (*Lates calcarifer*)and Mangrove Jack (*Lutjanus argentimaculatus*)
- for inshore harvest and recreational fisheries building resilience through repairing habitat is key. Research underway for the Great Barrier Reef catchments suggests that repairing degraded and non-connected seascapes would at least double the available biomass for Banana Prawns. This assumes 40% mortality of juvenile prawns to the food chain. Implications for efficiency in wild harvest, recreational catch and marine biodiversity are substantial.
- For aquaculture there are both opportunities and constraints:
  - e.g. for Barramundi (*Lates calcarifer*) there is potential for the industry to spread south as the climate warms
  - e.g. for Atlantic Salmon (*Salmo salar*), the Tasmanian aquaculture industry is already near its upper thermal limit during summer months, and there is opportunity to counter this constraint through selective breeding for a higher thermal tolerance
  - e.g. Southern Bluefin Tuna (*Thunnus maccoyii*), farmed in South Australia will be impacted by increasing summer water temperatures through changes in their metabolic demand
  - e.g. as waters warm further south, the opportunity to farm warm temperate species becomes a possibility e.g. Eastern Lobster, SBT and Yellowtail Kingfish in Tasmania
- from a social perspective there is a higher adaptive capacity in centres with larger populations and therefore more flexibility in employment choices, a broader range of skills and probably opportunities and capacity for innovation. It follows that those small regional coastal communities strongly reliant on wild harvest fishing are those most at risk from any negative impacts that accompany a changing climate.

In brief:
Continuous improvements to fisheries management will build on science knowledge. Key attributes that require science input include species life history, species interactions, habitat protection and repair, economic and market factors, population and economic modelling and the development of scenarios to understand availability of stock and resource sharing across sectors and the implications of a changing climate. Ongoing science to understand variations and changes in available biomass, both spatially and temporally and to facilitate including these findings in management arrangements is essential.

Case study: Climate Change – Tassal

As a primary producer, the climate plays an important role in our operations. Tassal maintains a comprehensive risk management system to manage the long term risks, issues and opportunities presented by climate change and respond accordingly.

Summer remains a challenging period in terms of fish growth and survival, particularly at our South East sites, with higher ocean temperatures creating operational issues that are unique to farming conditions in Tasmania.

In response, Tassal has developed considerable options for adaptation via selective breeding, modification of farming technologies and practices, and geographic diversification.

We engage scientists to identify emerging climate trends and system responses, and undertake comprehensive broadscale environmental monitoring, allowing us to identify any early indicators of concern.

Although warmer temperatures can be challenging over summer and management strategies reduce risk through geographic diversity and harvest planning, we have also seen improved growth as a result of higher temperatures. This is aligned with our selective breeding program (SBP) which produces fish with faster growth rates to reduce total time in water. To further support this opportunity we have adapted our stocking strategy to consider the different environmental profiles of each of our sites, with smolt inputs managed accordingly.

We are working with CSIRO to forecast marine conditions in South East Tasmania, to allow for improved operational planning and to assist with existing decision-making processes.

The current year (2016) has been relatively cooler since June and is now showing cooler conditions with temperatures for January 2017 forecasted to be quite cool compared to average conditions.

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e) the impact of these changes on recreational fishing;

Key points include:

- inshore species, the key recreational targets, because of their life history features are likely to have fluctuating populations as Australia experiences more extreme weather of rainfall / floods and droughts
- recreational fishing is often opportunist – and target species will vary not just with season but also species availability
- protecting and where possible repairing habitat to foster resilience are key strategies –
  - e.g. repair shellfish reefs to enhance shelter and resilience including first order buffer against risks of water quality events
  - e.g. wherever possible apply or improve legislation to protect and retain fresh, brackish and tidal wetlands and their connectivity
  - e.g. improve water quality / reduce soil erosion / minimise sediment movement to estuary and nearshore zones to maximise the productivity opportunities for seagrasses and other critical benthic flora
- in Australia's more populous regions such as most of the east coast from Cairns south and then west to Melbourne as well as south-west WA recreational fishing effort is substantial. As noted by the Productivity Commission, it is timely to start tracking recreational effort and catch as a major input to fisheries management arrangements.
- climate is just one stressor; for these same more populous regions the losses of habitat that have occurred over the last 200+ years are having a far greater impact than climate or indeed recreational effort on total populations and biomass
- further work is needed to disentangle and understand how our total populations of inshore species are changing and varying and where restoration ecology can deliver maximum gains in productivity; this will then allow the revenue secured from recreational fishing licences to be most cost-effectively applied in protection and repair of habitat and fisheries productivity
- for more marine sectors such as game fishing competitions, increased intelligence on ocean currents, temperatures and fish movements will be essential to ensure tournament success.

In brief:
Climate is just one stressor on inshore populations. Securing increased stock resilience is essential. Recognising the multiple factors affecting the recreational experience it is timely to take a more strategic approach to recreational fishing, encouraging licence arrangements in all states and the application of revenue so collected to improving resilience – habitat and fisheries productivity, and to enhance recreational amenity.

Case Study: Marine Fisheries and Aquaculture

Key points

- Following past over-fishing, Australian governments have sought to apply policies to reduce catch volumes, and thereby restore and maintain fish stocks. Generally, these have been successful in improving sustainability.
- A developing issue is weak knowledge of the impact of increasingly successful but unmanaged recreational fishing on some high-value fish stocks.
- Current policy settings are sometimes overly prescriptive and outdated. In particular:
  - most commercial fisheries are managed primarily though controls over fishing methods, despite long recognition that this is a relatively inefficient way of meeting catch constraints, and inhibits fishers from introducing more cost effective practices
  - recreational and Indigenous customary fishing activity is at best sporadically monitored and impacts on stock sustainability largely uncounted in fishery management regimes. This is despite the fact that recreational fishing is a popular pastime for millions of Australians, and that recreational catch rivals commercial catch for some species, placing pressure on some key stocks
  - governments differ in the extent to which they have adopted best practice fishery management techniques, which is leading to significant costs for fishers operating in some cross-jurisdictional fisheries, and risks to sustainability of stocks.
- Commercial fisheries should move as a default position to apply transferrable quota systems. This would result in fewer constraints on fishing practice and provide a more efficient and effective means of adhering to harvest limits.
- Recreational fishing needs greater recognition in fisheries management, and decisions on restrictions and facilities for fishers require development of a sound evidence base.
- The introduction of licensing for recreational fishers where not presently used, and the better use of licensing systems to manage fishing where they are used, will provide a means for better meeting the needs of both future generations of fishers and environmental outcomes.
- The value of access to fisheries is multifaceted, incorporating economic, social and cultural benefits. Allocation of access where there is competition for fisheries resources should seek to maximise this value.
- Indigenous customary fishing is given special recognition consistent with native title rights more generally. However, there is limited clarity about what these rights entail for catch limits, which is an outcome of customary fishing being generally exempted from fishery management regimes. There is relatively poor input from Indigenous people into fishery management. Effective incorporation of customary fishing into management systems would help resolve these issues.
- Benefits from dissolving boundaries via active cooperation in the management of critical cross-jurisdictional fish stocks are often recognised but only rarely delivered.
- Other improvements include making regulatory standards for protected species clearer, greater delegation of operational decision making to fishery managers and strengthening cost recovery arrangements.
- Little change in the regulation of aquaculture over the past 10 years has not impeded the sector’s growth. The major producing states already had several best practice regulatory features and other states have faced challenges that are predominantly non-regulatory in nature.

Productivity Commission 2016, *Marine Fisheries and Aquaculture*, Draft Report, Canberra.

Case Study: Mungalla coastal wetland restoration

Jim Wallace and Ian McLeod

For thousands of years, the coastal wetlands flowing into the Great Barrier Reef lagoon provided food and fibre for indigenous Australians and were sustainably managed for their spiritual and ecological values. Most of these wetlands were lost or degraded with the introduction of western agriculture and the building of earthern walls (or bunds) to reclaim land for pasture.

In 1999, the Mungalla wetlands east of Ingham was a typical degraded wetland. It was acquired by the Nywaigi Aboriginal Land Corporation and became part of a cattle grazing enterprise run by the Mungalla Aboriginal Corporation for Business (MACB). The MACB in partnership with advisors from CSIRO and TropWATER of James Cook University began to monitor and restore the wetland's ecology.

Massive weed infestations in Mungalla resulted in low dissolved oxygen and degraded its biodiversity. Herbicides were used to control the weeds but were expensive, ecologically undesirable and of limited success. After ten years, a more natural form of weed control using tidal ingress of seawater by removing an earth bund on the seaward side of the wetland was trialled. Hydro-dynamic modelling showed that during large tides seawater should penetrate well into the wetland. The earth bund was removed in October 2013 and seawater did indeed enter the wetland several times a year on the highest tides.

The ecological response was remarkable. Freshwater weeds were reduced immediately and became almost entirely absent within two years. Olive hymenachne decreased by 39% , water hyancinth by 76% and salvinia by 37%. Saltmarsh communities such as native sedges began to dominate the site and biodiversity has greatly improved. The greatest reward is that this method is ecologically sound and will continue, cost free, forever.

Then and now: (a) the massive infestation of weeds of national significance, before the bund was removed; (b) the enormous reduction in these weeds only two years after the bund was removed.

The successful restoration of the Mungalla wetlands is due to the combination of indigenous ownership and management with scientific monitoring and modelling – an approach that could well be applied to many of the still degraded coastal wetlands in north Queensland.

Picture of a successful partnership. From the left: Jim Wallace (hydrologist – TropWATER), Jacob Cassady (Station Manager – MACB) and Mike Nicholas (tropical weed ecologist – ex-CSIRO).

f) the adequacy of current quota-setting and access rights provisions and processes given current and projected climate change impacts;

Key points include:

- climate is one of many factors requiring science as an input to fishery management arrangements
- existing management arrangements will require continuous improvement as science knowledge increases:
  - e.g. with range expansion or range drift, whose fish is it?
  - e.g. spatial entitlements may need to be re-assessed over time as there will be both positive and negative impacts on existing entitlements
  - e.g. changing stock availability may need to be included in any quotas and/or preferably annual harvest entitlements
  - e.g. varying recreational controls such as bag limits may need to be revised
- fisheries management needs to be more agile in order to take advantage of opportunities that arise through climate change
- from a climate change perspective, there are substantial limits in our predictive capacity at this stage; certainly it is generally too early to specifically constrain / increase quota and access provisions due solely to climate change. Indeed it is preferable that management arrangements are multi-attribute based incorporating multiple science findings.
- what we can do is continually improve harvest management arrangements around key 'smart principles'; these include:
  - sustainability
  - adaptability
  - flexibility
  - responsiveness

  all underpinned by science such as stock assessment and bio-economic knowledge commensurate to the size and value of the particular fishery.

In brief:
Our broad goals must be to ensure profitable and secure food production, enhanced recreational experiences, sustainability of all harvest and healthy, resilient, biodiverse estuary, nearshore and marine ecosystems. An integrated approach incorporating science knowledge on climate, its variability and change into a broader more generic marine systems policy and management is recommended.

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g) the adequacy of current and proposed marine biodiversity protections given current and projected climate change impacts;

Key points include:

- changes in habitat are being observed
  - e.g. a rapid climate-driven regime shift of Australian temperate reefs has been documented with kelp forests replaced by persistent seaweed turfs
  - e.g. similarly the 2011 WA marine heat wave forced a 100 km range contraction of extensive kelp forests and saw temperate species replaced by seaweeds, invertebrates, corals and fish more characteristic of subtropical and tropical waters
  - e.g. climate models suggest for WA a progressive reduction in the strength of the Leeuwin current with implications for marine biodiversity; there may be a greater northward lobster migration and a shift in the biomass of this species, and presumably other species, toward the north
- in tropical regions changes in habitat quality and productivity declines seem likely though at this stage not well documented
  - e.g. the large mangrove dieback in the Gulf of Carpentaria may be climate related and further investigation is warranted
- there are limits in our predictive capacity; certainly it is too early in our understanding of the implications of a changing climate
- coral bleaching is of extremely high media profile
- increased investments in catchment water quality repair
- including climate change and habitat / productivity analysis in the next round of sustainability assessments is recommended
- No-take Marine Reserves are important benchmarks or reference points to understand and track change and to gauge the effectiveness of our marine management
  - e.g. Maria Island Marine Protected Area and its dual role of understanding the impacts of fisheries management and our changing climate
  - e.g. Elizabeth and Middleton Reefs, previously a National Nature Reserve and now within the Lord Howe Commonwealth Marine Reserve; these Reefs are a mixing zone of tropical and temperate species fish and corals without the confounding terrestrial influences such as water quality / tourist pressure / major ship movements / harvest activities. MEPAs such as these provide excellent sites to better understand implications of ocean temperature, pH changes and species movement.

In brief:
Marine reserves provide excellent reference sites upon which to build an understanding of the implications of a changing climate. As science understanding builds over the next decade there may be a need to re-visit marine and estuarine protected area boundaries and management arrangements.

Case Study: Role of Elizabeth and Middleton Reefs as a sentinel of change

The area of the former Elizabeth and Middleton Reefs Marine National Nature Reserve is located in the Tasman Sea approximately 600 kilometers east of Coffs Harbour. The former reserve includes two separate reefs, Elizabeth Reef and Middleton Reef.

Elizabeth Reef is at latitude 29°56'S and longitude 159°05'E. Middleton Reef is at latitude 29°27'S and longitude 159°07'E. Elizabeth and Middleton Reefs, together with reefs around Lord Howe Island 150 kilometers to the south, are regarded as the southernmost coral reefs in the world. Their location, where tropical and temperate ocean currents meet, contributes to an unusually diverse assemblage of marine species.

The former Elizabeth and Middleton Reefs Marine National Nature Reserve has been included within the larger new Lord Howe Commonwealth Marine Reserve. Transitional management arrangements apply until a management plan for the Temperate East Commonwealth Marine Reserves Network is in place.

The Reefs are the peaks of volcanic seamounts, which are part of the Lord Howe Island volcanic chain. Together with Lord Howe Island, Elizabeth and Middleton Reefs form the world's most southern coral reefs. Warm currents during summer and cold currents during winter, together with the remote locations of the reefs; have resulted in unique assemblages of tropical and subtropical species.

The remote location also means replenishment from distant reefs is at most infrequent, that more than likely most species are self-replenishing and that there are no water quality issues such as those affecting the Great Barrier Reef.

Elizabeth and Middleton Reefs are ideal sites to study the biotic implications of a changing climate.

h) the adequacy of biosecurity measures and monitoring systems given current and projected climate change impacts;

Key issues include:

- Biosecurity measures and monitoring fall within the core remit of the Department of Agriculture and Water and their partner State agencies. FRDC invests in research on a needs basis as required to support emerging issues.
- The FRDC manages and prioritises its investments through the *Aquatic Animal Health and Biosecurity* subprogram and via sector-specific industry partnership agreements.
- Australia has a unique and poorly understood range of endemic pathogens including local strain variations of pathogens of international concern, which is becoming increasingly important and of significance to our export trade. Examples include:
  - nervous necrosis virus in finfish
  - local genotypes of YHV (YHV2, YHV7) in prawns
  - *Bonamia* sp. in edible oysters
  - oedema oyster disease in pearl oysters
  - *Edwardsiella ictaluri* in catfish
  - abalone viral ganglioneuritis and
  - *Penaeus monodon* hepatopancreatitis.
- Endemic diseases compromise Australia’s export of aquatic animal products e.g. live shellfish. Trade barriers, based on our lack of understanding of our own diseases, will continue to be imposed and provide an incentive to improve basic knowledge on endemic disease agents, and how to improve the quality control and thus international acceptance of our diagnostic and surveillance capacity.
- Under Aquaplan 2014-2019 and the FRDC Strategic Plan investments are within the following broad areas:
  - nature of disease, threats to aquatic animals in Australia
  - aquatic animal health and biosecurity management
  - endemic and exotic aquatic animal disease diagnostics
  - surveillance and monitoring
  - aquatic animal disease therapy and prophylaxis
  - training and capacity building

In brief:
FRDC confines its investment in biosecurity to endemic diseases and to risks associated with exotics that currently or potentially have an impact on or by fishing and aquaculture activities. Climate and climate change is included in research projects as appropriate.

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i) any other related matters.

Key points include:

- innovation in the marine space continues
  - e.g. algae-based aquaculture for multiple benefits of food production plus carbon sequestration plus energy generation plus acid sulphate amelioration
  - e.g. aquaculture production systems and tactical activities to cope with weather extremes
- habitat repair of mangrove, salt marsh and seascape environments delivers a major carbon sequestration outcome; these seascapes are the highest per hectare of all carbon sequestration opportunities, well higher than all other terrestrial landscapes
- sea level rise, if rapid, could lead to poorly planned shoreline and infrastructure protection; this would markedly disadvantage key inshore and nearshore habitats and therefore fisheries productivity and marine biodiversity
- climate should not be a 'stand alone' basis for decisions; multiple factors must be included in any management regime. There are multiple objectives, multiple users and multiple benefits. Climate, its variability and change should be part of the broader area of marine systems policy and management.

In brief:
Knowledge is key. Building climate considerations into marine systems policy and management requires a strategic multi-objective science-based approach and will deliver multiple benefits.

3 – Adapting our management of marine environments to a changing climate

Adapting to a changing marine environment is a continuous process with science informing management. Management builds on science findings using the various tools at hand and innovating in both policy and actions to work closely with the users towards the shared objective of sustainable marine Australia.

In analysing Australia's progress Creighton et al.(2015) grouped the various elements of continuous improvement within three broad phases – preconditioning, future proofing and transformation / opportunity. This provides a useful strategic framework within which to track Australia's progress.

Phases in Australia's response to a changing marine environment
Preconditioning => Future Proofing => Transformation / Opportunities
Checklist of Imperatives
Flexible + Adaptive + Resilient + Integrative + Responsive
Key Groups of Activities
1. Providing knowledge to equip marine users & managers
2. Rethinking marine management paradigms
3. Repairing inshore fisheries to guarantee increased productivity & resilience
4. Fostering climate-informed action through smart extension and shared knowledge
5. Contributing to smarter energy use

With this strategic framework there are a suite of imperatives that can be used as a checklist or set of criteria upon which to assess proposed policy and management arrangements and to explore opportunities. Flowing on from this checklist we can collate activities that are currently and/or likely to be part of Australia's ongoing response.

This structure of a high level strategic framework, further refined by a checklist of imperatives and defined by example activities, might provide the Senate Inquiry with a useful basis within which to tabulate various submissions and assess Australia's progress.

Summary of the elements for guiding and assessing policy and management change (ex: *Adapting Management of Marine Environments to a Changing Climate: A Checklist to Guide Reform and Assess Progress*, Colin Creighton, Alistair J. Hobday, Michael Lockwood & Gretta T. Pecl 2015	
Stage/Phase	Element
Preconditioning	Policy and management need to respond to changing social-ecological conditions, so interventions must be as dynamic as the systems they seek to influence.
	Action for climate adaptation must be a part of larger social and economic adaptations to changing circumstances.
	Climate policy should be implemented as part of integrative, multi-objective policy and management.
	In responding through fisheries management interventions to changing interactions, it is essential to include climate influences.
Future proofing	Fostering resilient healthy ecosystems is an imperative for policy and management.
	Policy and management must address spatial and temporal scales that match the values and issues of concern.
	Catchment management is essential for positive marine outcomes.
	In responding to threatening processes, it is essential to ensure ecosystem integrity.
	In protecting key species, site- and species-specific strategies are essential.
Transformation and opportunity	Changes brought about by a changing climate must be assessed for beneficial opportunities.
	In responding to increased climate variability and change, a transition towards flexible total stock management systems is essential.
	Policy and management must take advantage of the key role marine ecosystems can have in carbon sequestration.
	Carbon sequestration in marine systems is best done as part of a multi-objective approach.

3a) Imperatives for enhanced marine biodiversity and fisheries management

A changing climate is already leading to altered physical conditions and ecological assemblages. Likewise it is leading to altered responses, economic opportunities and conservation priorities. Most importantly, climate and its impacts is but one of many issues that need to be part of our input to management decisions. Indeed, marine management by virtue of being multi-objective and meeting diverse and sometimes-competing user needs is best served by incorporating climate knowledge as one of many issues to be accommodated in management. With this broader holistic scope setting the context a checklist of criteria on which to assess proposed policy and management arrangements from a climate perspective can be useful.

Descriptors are likely to include **flexible, adaptive, resilient, integrative** and **responsive.**

The checklist of criteria should include:

Dynamic, changing and responsive

Inshore, coastal and marine systems are dynamic. Our responses to a changing and more variable climate must also be dynamic and flexible.

Climate adaptation – a part of much larger social and economic adaptation

Climate change adaptation is part of the broader need to adapt to changing economic and social conditions. Climate change adaptation is best undertaken as part of the overall management process for inshore, coastal and marine systems.

Climate – part of integrative, more multi-objective policy and management

Marine policy approaches include concepts such as ecosystem-based management, managing complexity, integrated monitoring and assessment, fostering regional economies, and ensuring food security. Climate and a changing climate is just part of this much more complex agenda.

Management approaches – developing policies that match in coverage what we seek to manage

Australia's marine managers in the previously developed National Action Plan for Fisheries and Aquaculture sought to respond to our changing climate by proposing a regional approach to fisheries management – south-east, tropical and western. Climate is just one of the drivers towards this more holistic approach to cross-jurisdiction marine management.

Minimising the impact of extreme events – an imperative for fostering resilient healthy ecosystems

If we protect, repair, use and conserve inshore and marine resources for our sustainable benefit then the productive healthy ecosystems will be resilient to perturbations such as extreme events. Marine management must include fostering healthy ecosystems so that where possible the deleterious impacts of extreme climate events are minimised. (These extreme events include marine current heat waves, cyclones, terrestrial droughts [and therefore lack of freshwater run-off to foster productivity in our estuarine and nearshore zones] and terrestrial floods [and often major fish kills from de-oxygenation, massive increases in sediment load and sudden changes to water chemistry such as acidic effluent from drained wetlands that accompanies floods]).

Catchment management – essential for marine outcomes

Marine, estuarine to riverine ecosystems are inter-linked with two-way flows of material and biota. The health and vigor of these systems is adversely impacted by effluent from catchment uses. Climate change and the increasing likelihood of extreme flood events with ability to dump higher loads of effluent in receiving waters makes it even more imperative to reduce catchment effluent – sediments, nutrients and poisons – all of which adversely impact on the productivity, health and resilience of riverine, estuarine and marine ecosystems.

Responding to variability – towards flexible total stock management

A changing and more variable climate will lead to changing and more variable fish stocks. Populations will change in both quantity and location. Incorporating climate impacts in fisheries management requires management processes, opportunities and controls to incorporate temporal and spatial variations in the target stock or the ecosystems that sustain that stock. Early detection of stock changes is essential as spawning stocks can become depleted if there is a downturn in recruitment that is undetected and fishing pressure is maintained. For example, the Western Rock Lobster fishery avoided any reduction in spawning stock because of its early intervention on the decline in recruitment. However early intervention in the Shark Bay scallop fishery that resulted in the closure of the fishery did not avoid a major reduction in the spawning stock because of the severity of the recruitment downturn and the high level of adult mortality.

Responding to changing interactions – including climate influences in any assessment

Fisheries management already seeks to take adequate account of multi-species and species –habitat interactions. Climate is part of what influences these interactions so that any changing climate and its impact on interactions will also need to be taken into account.

Responding to threatening processes – to ensure ecosystem integrity

Conservation management should focus on ecosystem integrity including stocks, flows, fluxes and ecosystem processes and must seek to minimise any threatening processes that impact on ecosystem integrity. Providing marine park protective management for a suite of representative ecosystems, bioregion by bioregion, without simultaneously seeking to minimise the impact of all threatening processes will prove to be insufficient for biodiversity conservation. A changing climate will change the impact of many threatening processes. A changing climate also demonstrates that static management responses such as hard and fast marine park zonings and boundaries may prove to be inadequate.

Responding to non-static conditions – policy, procedures and regulations must be as flexible as the stocks and ecosystems we seek to manage

Both fisheries and conservation management must recognise the dynamic nature of inshore and marine resources. There is no static or set of climax communities that we must strive to protect in say '1770 condition'. Our adaptive interventions must focus on seeking to ensure greater resilience so the ecosystems have the capacity to sustain shocks such as extreme climate events while recognising that there will be change such as those bought on by a changing and more variable climate that are beyond our ability to readily reduce.

Repairing for increased resilience – a priority for investment

The marine resources most degraded are the inshore and coastal resources – estuaries, wetlands and the nearshore zone. These are also the resources most at threat from extreme climate events. Increased focus on repair and investment will enhance their resilience and optimise the multiple public benefits we derive from these inshore and coastal resources.

Protecting key species – site- and species-specific strategies will be essential

A changing climate will impact on key species of high conservation value such as seabirds and marine mammals. Site and species specific-management to minimise the impacts of a changing climate is essential if we are to conserve these populations, their roosting or resting, breeding and feeding regimes.

Changing climate – a profitability opportunity

Some stocks will be advantaged by a changing climate (e.g. increasing Eastern Rock Lobster range over Southern Rock Lobster range that will decline). Likewise some production systems will be benefited (e.g. expansion south of suitable environments for Barramundi aquaculture) and others may decline. A positive facilitative approach to industry development is essential and will be informed through value chain analysis and the identification of key opportunities.

Marine ecosystems – a role in carbon sequestration

Coastal, nearshore marine and estuarine ecosystems, by virtue of being the most productive of the world's ecosystems are also the highest per hectare sequesters of carbon. Coastal, nearshore marine and estuarine ecosystems need to be incorporated in Australia's National Carbon Accounts and play a significant role in Government investment programs.

Carbon sequestration – part of a multi-objective approach

Similar to adaptation being multi-faceted, Australia's investments in climate change mitigation could most usefully focus on those opportunities that also provide multiple other benefits to the Australian community and economy. From a marine perspective, repairing coastal ecosystems of seagrasses, mangroves, salt marshes and floodplain wetlands provides not only the highest per hectare carbon sequestering opportunity but also deliver outcomes for Australia's food security, regional employment and biodiversity.

3b) Climate change related activities and opportunities for investment

Based on the proceeding suite of criteria various current activities and further investment opportunities can be grouped within five broad areas:

1. Providing knowledge to equip marine users & managers

Commissioning research to provide knowledge is core business for the FRDC, the National Environmental Science Program within the Department of Environment and other key investors such as Australian, State and Territory Government agencies. Providing research findings is core business for Australia's major research institutions and universities.

Findings to date against the Senate Inquiry's Terms of Reference were summarised previously. Section 6 summarises recent relevant completed research projects commissioned through FRDC. Section 7 illustrates some of the relevant research projects commissioned through FRDC and currently in progress.

The broad areas of research investment include:

- ✓ improving marine forecasting and ocean current / eddy forecasting as a key input to a whole host of marine user decisions (e.g. ship movements, defence, fisheries, oil and natural gas extraction)
- ✓ developing smarter and real-time stock assessment and population predictions (e.g. to foster a more profitable and climate-responsive fishing sector)
- ✓ determining and evaluating cheaper and more user / outcome-orientated monitoring systems (e.g. to calibrate projections of change, to provide the basis for stock assessment and to inform the effectiveness or otherwise of our management interventions)
- ✓ improving predictive understanding of biological trajectories for our marine environments as they respond to all changes and impacts (e.g. to underpin any changes to marine park reservations, fish stocks and overall marine biodiversity management).

All research commissioned by FRDC is required as part of contract conditions to provide any resulting data such as spatial data sets in forms that can then be uploaded on the Integrated Marine Observing System (IMOS). This is essentially a digital library with all uploads specified to ANZLIC metadata standards. Research is costly. The vision is to maximise the opportunity for others to access and then apply these data sets for their specific applications.

Most recently there have been calls to build onto IMOS a 'back end' – a suite of analytical functionalities. This would allow for combining data sets and interpreting, cross comparing and visualising the vast stores of data from the user or knowledge perspective. This would greatly facilitate analysis of multiple data sets together in real time. The specifications of such add-on functionalities to IMOS will need to be defined by the various users. This opportunity for specific and immediate investment is explored further in Section 3c).

2. Rethinking marine management paradigms

Much of our marine management to date has had a static basis. Examples include specific use zones in the Great Barrier Reef Marine Park, specific marine park boundaries in both State and Commonwealth waters and specific spatial entitlements for various fishing activities. These spatial boundaries have often been used as a surrogate for broader objectives such as species protection and/or management. However, species are on the move. Increasingly marine managers are thinking through how best to be more adaptive to change. For example:

- ✓ fostering the transition towards total population management for key target species (e.g. total fisheries stocks rather than jurisdiction by jurisdiction-based management arrangements)
- ✓ encouraging more adaptive and user-friendly management systems (e.g. more flexible conservation and fisheries management)
- ✓ enhancing market and food security opportunities.

Rethinking our marine management paradigms will take time and is probably best regarded as a long-term multi-objective journey informed by science and responding to increasing awareness from all sectors of the implications of a changing marine environment on all users.

3. Repairing inshore fisheries to guarantee increased productivity & resilience

As detailed in the responses to the Terms of Reference, Australia’s inshore fisheries are particularly susceptible to our changing and more variable climate. For many species the triggers for movement and breeding are strongly linked to the nature and extent of rain / flooding events. With a more variable and often drier climate populations are likely to also be more variable and reduced. For the multiple imperatives of food supply, commercial industry profitability, biodiversity conservation and recreational amenity it is essential that we repair as much estuary and nearshore habitat as is possible, maximising the opportunities for marine productivity.

Inshore species and their habitats are also susceptible to the impacts of extreme climate events. A well-documented example is the dumping of excessive sediments on seagrass beds, smothering the seagrass, markedly reducing their photosynthetic ability and thereby greatly affecting the available habitat for many crustacean species (e.g. tiger prawns) and high conservation value species (e.g. dugongs). A second example is the benefits of repairing shellfish reefs and their role in assimilating nutrients and sediments from runoff events while simultaneously providing additional habitat and food sources for many marine species.

There is growing momentum around the broad concepts of restoration ecology for Australia’s estuaries, wetlands and nearshore zones. These ecosystems are Australia’s most damaged, broadly as a function of history and our various coastal development activities and industries with, in some cases such as the Great Barrier Reef catchments, in excess of 80% of previous brackish fisheries habitat lost – essential for species such as Barramundi, Banana Prawn and Mangrove Jack to cite just several key commercial and recreational target species. Likewise, for most of Australia our shellfish reefs are regarded as 'functionally extinct'.

Within the Great Barrier Reef catchments works investment in wetland repair is increasing. Likewise across southern Australia there is increasing attention being paid to repairing salt marshes and shellfish reefs. Repair will foster productivity and resilience. This opportunity for specific and immediate investment is explored further in Section 3c).

4. Fostering climate-informed action through smart extension and shared knowledge

Science findings and management responses are only ever as good as their rate of adoption by the Australian community. Certainly many of Australia's commercial fishers, by virtue of living with and responding to weather events are well aware of Australia's changing climate. Increasingly the recreational fishing sector is also becoming well aware, probably largely due to unexpected catches of species previously considered to be well outside their range (e.g. press in various magazines about Mahi-Mahi catches in Tasmanian waters).

One of the standout extension tools has been the initiative known as Redmap (see case study on page 8). Continued investment in citizen science programs such as this to build greater awareness across the Australian community of the implications of a changing climate, the need to repair habitat for productivity and resilience and the imperative that we re-think our various management arrangements is strongly recommended.

5. Contributing to smarter energy use

The issues and opportunities for mitigation and energy generation are broadly beyond the core Terms of Reference for this Inquiry. Suffice it to say total marine management to benefit the Australian economy is likely to include:

- ✓ reducing the carbon footprint of all marine users
- ✓ improved energy-efficient and carbon-smart aquaculture
- ✓ including algae energy systems in investment analysis of bio-energy opportunities
- ✓ ensuring coastal ecosystems with their extremely high potential for carbon sequestration are included in the National Carbon Accounts.

There will always be calls for more information, more research and improved policy and management. The challenging task is to determine what is essential, what is on the critical path to success and how best to focus what will always be limited resources. This submission outlines two crucial areas for immediate implementation – improved knowledge generation through better access to data and enhanced marine resilience through habitat repair as outlined in Section 3c.

3c) Immediate Investment Priorities

Data=> Information=> Knowledge

One of the eight key recommendations from *The National Marine Science Plan 2015-2025* is to foster enhanced decision-making by policy makers and marine industry.

To cite: *Goal: Improve the scientific evidence base and the available decision-support tools for those managing the impacts of multiple and cumulative drivers and pressures on marine systems.*

We need to enhance the science – manager interface by building analytical frameworks, data visualisation techniques and manager-responsive information sets that capitalise on our many science investments and ensure the data sets within Australia's Integrated Marine Observing System (IMOS) from across multiple areas and individual science projects can be readily applied to the challenges ahead.

Within Australia and also internationally we already have the ability to develop ocean climate models using key monitored attributes such as temperature, current flows and ocean chemistry. These attributes and an understanding of habitat can be used to provide very useful proxies for fish distribution.

Such models are already assisting management. For example, with Southern Bluefin Tuna, the Australian Fish Management Authority sets the rules in various zones based on the CSIRO habitat maps that are used essentially as a proxy for where the Tuna are likely to be at different times of the year. To include considerations of a changing climate the models need to be run for longer periods and outputs provided for both seasonal and inter-annual time periods. This type of integrated multi-attribute modelling can also provide an indication of the likely contraction and/or expansion of various species and assemblages. A good example is the CSIRO Atlantis model that can be used to test the adaptability and resilience of a fisheries management system to expected changes, including more rapid ocean warming and implications for fish stocks.

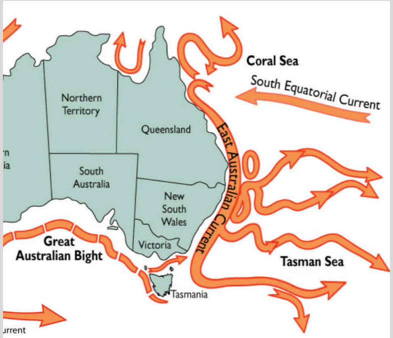
Any new investment in this broad space of enhancing the ability for managers to make effective decisions in a rapidly changing environment would need to be done in phases. These could be:

i. scoping – understanding the various groups of marine applications from fisheries management to biodiversity conservation, ship movements and weather predictions that would benefit from such an investment (year 1)
ii. critical evaluation of these opportunities – developing business cases that assess the benefits likely to accrue and at what cost (year 2)
iii. IMOS enhancement – possibly use pre-existing analytical software programs to access the IMOS data repository. There are R packages and scripts that enable anyone to query, access and then use data from massive online data repositories such as FishBase or GenBank. These could be applied to access the IMOS data repository (year 3).
iv. User-lead investment that build on the IMOS enhancement by using specific modelling routines to suit their particular knowledge needs (ongoing and user funded)
v. Review – assessing the benefits of the investment in the add-ons of the analytical systems to IMOS, determining key gaps within IMOS data sets that if filled would enhance outputs and suggesting next steps.

Why is the East Australian Current behaving so badly?

18th October 2016

The East Australian Current (EAC) is a flow of water that is formed from the South Equatorial Current crossing the Coral Sea and reaching the eastern coast of Australia off Queensland. As the South Equatorial Current hits the Australian coast it divides forming the southward flow of the EAC.

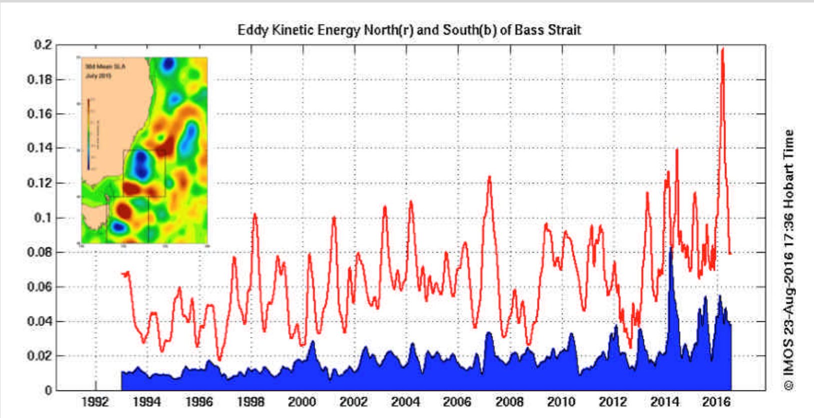


The EAC is the largest ocean current close to the shores of Australia reaching a maximum velocity at about Coffs Harbour in NSW where its flow can reach a speed of 3 km per hour.

In the animated film Finding Nemo Marlin and Dory use the EAC as a superhighway travelling with fish and sea turtles to Sydney Harbour. The EAC is dominated by eddies which are circular currents of water that form whirlpools of up to 100 km in diameter.

Their swirling motion is one of the forces that make nutrients found in cold, deep waters to come up to the surface of the ocean where phytoplankton (microscopic plants) feed on them.

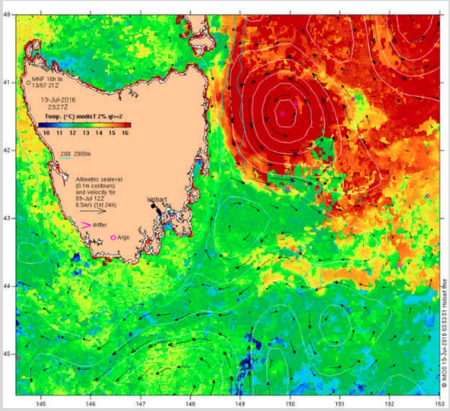
Eddies do occur off the coast of Tasmania but a change in their behaviour over the last 24 years is concerning. These eddies are generated in the EAC and most of them do not go south of Bass Strait. When they do, they bring warm water with them and the bigger they are the more heat they can bring.



Scientists have noted a trend in eddies off Tasmania becoming larger, stronger and more frequent. Following the 1990s, eddy kinetic energy (EKE) increased gradually both north (red line in graph below) and south (blue line in graph below) of Bass Strait, with a huge spike in eddy activity off Tasmania (8 times the average EKE of the 1990s) in 2014 (see animation below). This trend is in agreement with climate modelling but there has been a dramatic increase over the last couple of years.

The presence of eddies south of Bass Strait is believed to be responsible for the atypically warm sea surface temperatures experienced off the east coast of Tasmania in 2015. If the eddy encountered off north east Tasmania in July this year is anything to go by (see image below), this heating trend is expected to continue into 2016.

A team of CSIRO scientists, AFMA observer and commercial fishermen from the South East Trawl Fishery came upon the eddy while conducting acoustic surveys of orange roughy off the north east coast of Tasmania in July 2016 as part of an ongoing monitoring program.



It was fast and hot and gave the team a bit of a hard time by making the deployment and retrieval of their sampling gear very challenging.

The eddy had current speeds of more than 2 knots and temperatures at its centre were more than 2 degrees warmer than the year round average between 100–400m depth and almost 1 degree warmer at 1200m depth. The eddy's outer edge was close to the continental slope.

The implications of increased eddy activity on adult orange roughy spawning, orange roughy larvae, aquaculture, other fisheries and Tasmanian coastal waters in general are unknown. However, hot eddies warm up all the water around them and the bigger they are the deeper and wider their impact so if this trend continues there is no doubt that the Tasmanian offshore environment will change – the 'how' is anyone's guess!

For up to date ocean information around Australia visit the IMOS Ocean Current website.

South East Trawl Fishing Industry Association Oct 2016 (SETFIA www.setfia.org.au)

Repairing inshore fisheries to guarantee increased productivity & resilience

One of the eight key recommendations from *The National Marine Science Plan 2015-2025* is to build science capability in restoration ecology and eco-engineering.

To cite: *Goal: Develop solutions for repairing ecosystems and design ecosystem-friendly marine structures.*

Building resilience in our estuarine, nearshore and marine ecosystems would ensure that our biological systems are healthy, well buffered and can respond to rapid changes such as major shifts in climate and the predicted more extreme events.

This can be achieved by repairing habitat, improving water quality, minimising in-situ pollution such as marine plastics and oil spills and by reducing deleterious impacts from our terrestrial catchments. The various activities underway for Australia's Great Barrier Reef including inter-Government leadership, collaboration across sectors, strategy planning and long-term targets, five-yearly reporting of progress, public and private investment partnerships, catchment repair and wetland re-establishment provide an excellent model for that required across Australia to ensure a resilient, profitable and sustainable marine Australia.

Creighton (2014) developed a Business Case on the costs and benefits of a major initiative to repair estuary and nearshore fisheries productivity. The suggested high priority investments totalled just over $300M and the break-even point for investment in terms of increased fisheries production as valued by Sydney Fish Market prices was less than five years. Some of these proposed works are already receiving funding, indicating the robustness of the Business Case.

In several high profile repair areas such as shellfish reef repair, wetland repair and connectivity within Great Barrier Reef catchments, investment is a mix of philanthropy and Government funding. Certainly repairing habitat is a high priority across all sectors of the fishing industry – commercial, recreational and aquaculture. Indeed in those states already having in place a recreational fishing levy much of the funds so collected are being allocated to habitat repair.

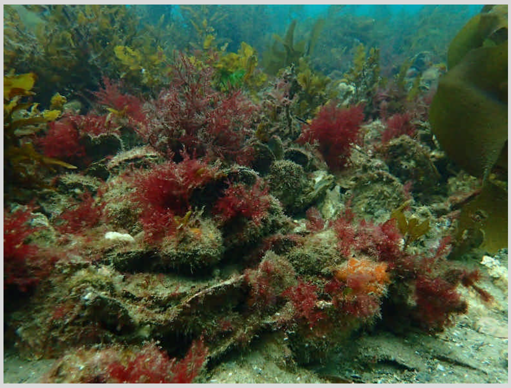
Any catalytic investment recommended by the Senate Inquiry in this broad space of enhancing productivity and resilience would need to be undertaken in close cooperation with State Governments, the entire fishing sector and various community groups. Over time, as all States develop their own particular form of recreational licensing such an initiative could be achieved totally independent of consolidated revenue.

The accompanying case study on shellfish reef repair provides an example. This initiative is coordinated through The Nature Conservancy, has attracted co-investment from all fishing sectors and relevant Australian and State agencies in a series of public – private partnerships. Repairing shellfish reef works are underway across all of southern mainland Australia – WA, SA, Vic, NSW and Qld with projects also about to start in Tasmania (see 'Reef Revival' Fish Volume 24(3) September 2016 Fisheries Research and Development Corporation News).

Case study: Shellfish Reef Repair

In 2014 The Nature Conservancy Australia (TNC) launched its Great Southern Seascapes program to catalyse large-scale repair of marine habitats in temperate bays and estuaries. To date, the program has raised over $7 million in private and philanthropic funding to support the restoration of shellfish reef habitats with restoration works underway in Port Phillip Bay, Gulf St Vincent and Albany. These projects are delivered in partnership between TNC, state government fisheries and environmental agencies, recreational fishing peak bodies, local fishing clubs and businesses. The Commonwealth Government Department of Infrastructure (National Stronger Regions Fund) recently awarded TNC $1M in funding to support the restoration of 20 ha of shellfish reef in Gulf St Vincent which will create up to 27 fulltime equivalent jobs in recreational fishing, marine construction, science and technology, and the visitor economy.

A) 

B) 

Shellfish reefs provide important fish habitat but where largely wiped out during the late 1800s through dredge fishing, poor water quality and sedimentation. (A) remnant shellfish reef, Port Phillip Bay, Victoria (B) Native flat oyster reef, St Helens Tasmania

4 – Concluding comments

This submission to the Senate Inquiry has focused on the role of science in informing fisheries and ecosystem management. Other submissions such as those from the Australian Fisheries Management Authority, the Department of Agriculture and Water and the Department of Environment and Energy will also approach the Inquiry Terms of Reference from the management perspective.

Strong partnerships between science enquiry and management assist in defining the nature of science required. Capitalising on knowledge learnt via extension and interaction between science providers, policy makers, managers, fishers and the broad community is equally essential. FRDC welcomes this Senate Inquiry, its consideration of the various issues facing marine Australia as we adapt to a changing climate and is available to assist the Inquiry as might be required.

5 – Further information

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Note: There are many more science papers resulting from FRDC and related research investments. This list simply provides a quick checklist to further information elaborating on the various dot points in Section 2 of this Submission.

6 – Summary of recent FRDC climate change related R&D findings

Terms of Reference
(a) recent and projected changes in ocean temperatures, currents and chemistry associated with climate change;

FRDC#2009/056 Understanding the biophysical implications of climate change in South East Australia: Modelling of physical drivers and future changes

Term of Reference
(b) recent and projected changes in fish stocks, marine biodiversity and marine ecosystems associated with climate change;

FRDC#2009/070 Risk Assessment of Impacts of Climate Change for Key Species in South-Eastern Australia

FRDC#2010/023 Potential futures for Australia's south eastern marine ecosystems, quantitative Atlantis projections

FRDC#2010/554 Effects of climate change on reproduction, larval development, and population growth of coral trout (*Plectropomus* spp.)

Term of Reference
(d) the impact of these changes on commercial fishing and aquaculture, including associated business activity and employment;

FRDC#2010/521 Vulnerability of an iconic Australian finfish (Barramundi, *Lates calcarifer*) and related industries to altered climate across tropical Australia

FRDC#2010/534 Ensuring the Australian Oyster industry adapts to a changing climate: a natural resource and industry spatial information portal for knowledge and informed adaptation frameworks

FRDC#2011/040 Estuarine and nearshore ecosystems – assessing alternative adaptive management strategies for the management of estuarine and coastal ecosystems

FRDC#2012/036 Revitalising Australia's Estuaries

Term of Reference
(e) the impact of these changes on recreational fishing;

FRDC #2010/524Identification of climate-driven species shifts and adaptation options for recreational fishers: learning general lessons from a data rich case

FRDC#2011/037 Implications of climate change for recreational fishers and the recreational fishing industry

Term of Reference
(f) the adequacy of current quota-setting and access rights provisions and processes given current and projected climate change impacts;

FRDC#2009/055 Development and testing of a national integrated climate change adaptation assessment framework

FRDC#2009/073 Identifying management objectives hierarchies and weightings for four key fisheries in South Eastern Australia

FRDC#2010/532 Changing currents in marine biodiversity governance and management: responding to climate change

FRDC#2010/535 Management implications of climate change effect on fisheries in Western Australia

FRDC#2010/565 Implications of climate change on fisheries resources of northern Australia. Vulnerability assessment and adaptation options

FRDC#2011/039 Preparing fisheries for climate change – assessing alternative adaptive options for four key fisheries in south-eastern Australia

FRDC#2011/233 Growth opportunities & critical elements in the supply chain for wild fisheries & aquaculture in a changing climate

Term of Reference
(g) the adequacy of current and proposed marine biodiversity protections given current and projected climate change impacts;

FRDC#2010/506 Adaptive management of temperate reefs to minimise effects of climate change: Developing new effective approaches for ecological monitoring and predictive modelling

FRDC#2010/510 Adapting to the effects of climate change on Australia's deep marine reserves

FRDC#2010/533 Developing adaptation options for seabirds and marine mammals impacted by climate change

FRDC#2010/564 Pre-adapting a Tasmanian coastal ecosystem to ongoing climate change through reintroduction of a locally extinct species

Term of Reference
(i) any other related matters.

FRDC#2011/503 Climate Change Adaptation: Building community and industry knowledge

FRDC#2010/536 Beach and surf tourism and recreation in Australia: vulnerability and adaptation

FRDC#2010/542 A marine climate change adaptation blueprint for coastal regional communities

FRDC#2011/084 Comparative sequestration and mitigation opportunities across the Australian landscape and its land uses

Notes:

Many of these projects go across several Terms of Reference. Projects have been nominally assigned to the principal TOR in this listing.

Detailed summaries and supporting graphics for all these projects can be found in Creighton, C 2014 – *Marine Australia –Directions for management and further research*. This is available on the FRDC website – FRDC#2009/074

7 – Examples of FRDC R&D&E underway that include climate change considerations

Term of Reference
(a) recent and projected changes in ocean temperatures, currents and chemistry associated with climate change;

FRDC# 2016-005 eSAMarine – phase 1: the first step towards an operational now-cast/forecast ocean prediction system for Southern Australia
Principal Investigator: John Middleton
1. Develop a phase 1, demonstration now-cast/forecast system (including web delivery) for ocean currents, temperature and sea level for the southern Australian shelves, gulfs and bays that addresses the needs of industry (fisheries, aquaculture) and government.
2. Key stakeholders trained in the use and interpretation of now-casts/forecast results delivered by the investigators or web.
3. Determine and document future improvements to improve delivery of needs and model skill to provide a basis for a future Phase 2 of the now-cast/forecast system.
4. Build a hind-cast ocean circulation climatology that will be of future use in understanding the oceanographic influences on other fisheries.

FRDC# 2014-031 TSGA IPA: Predicting marine currents, nutrients and plankton in the coastal waters of south-eastern Tasmania in response to changing weather patterns
Principal Investigator: Christine Crawford
1. Build on available data to establish baseline environmental conditions in south-eastern Tasmanian coastal waters to support informed expansion of finfish farming in this region.
2. Enhance risk assessments underpinning Decision Support Systems for effects of changing weather and current patterns on water temperature, nutrients and plankton, especially in relation to HABs and gelatinous zooplankton.
3. Trial and establish a screening program for *Neoparamoeba perurans*, the causative agent of AGD.
4. Obtain measurements of primary productivity in Storm Bay and link to environmental drivers.

Term of Reference
(b) recent and projected changes in fish stocks, marine biodiversity and marine ecosystems associated with climate change;

FRDC# 2014-025 SRL IPA: Developing cost-effective industry-based techniques for monitoring puerulus settlement in all conditions: Phase 2
Principal Investigator: Stewart Frusher
1. To determine an appropriate and cost-effective sampling strategy (number of collectors, depth and time) to enable statistically meaningful analysis of spatial and depth trends in puerulus settlement.
2. To compare shallow and deep water survey methods (e.g. diver-based, fisher servicing) to establish the most cost-effective methods for ongoing monitoring of puerulus settlement.

FRDC#2014-019 Developing a fishery independent estimate of biomass for snapper
Principal Investigator: Mike Steer
1. To develop a DEPM for snapper that provides the most accurate estimate of biomass and integrates with the ongoing assessment and management of the resource.

FRDC#2014-012 Tasmania's coastal reefs: deep reef habitats and significance for finfish production and biodiversity
Principal Investigator: Jeremy Lyle
1. Characterise reef fish communities on the east and south-east coasts of Tasmania by depth and habitat structure.
2. Describe habitat associations for the key reef fish species and their links to life history characteristics.
3. Assess the potential to use habitat characteristics to describe and predict fish community structure.
4. Assess the significance of reef habitats for fisheries production and fishery assessments.

FRDC#2013-006 The impact of habitat loss and rehabilitation on recruitment to the NSW Eastern King Prawn fishery
Principal Investigator: Matt Taylor
1. Determine to what extent young Eastern King Prawns (EKP) are using natural, degraded or rehabilitated habitat in estuaries, and the contribution of these habitats to the fishery.
2. Determine the hydrographic conditions which provide for maximum growth and survival of EKP within nursery habitats.
3. Determine the extent of key EKP habitat lost and remaining in a number of key estuaries between the Tweed and the Hawkesbury.
4. Outline the potential improvements to the EKP fishery that could be achieve through targeted wetland rehabilitation and freshwater flow management.
5. Extend information on EKP habitat requirements to commercial fishers, landowners and other catchment stakeholders and incorporate recommendations into fisheries or water management.

FRDC#2015-026 Understanding recruitment variation (including the collapse) of Saucer Scallop stocks in Western Australia and assessing the feasibility of assisted recovery measures for improved management in a changing environment
Principal Investigator: Mervi Kangas
1. Understanding factors influencing recruitment variations in existing Scallop WA stocks, particularly the collapse of the stocks in 2011.
2. Determining feasibility of re-establishing founder population of Scallops in the Abrolhos Islands and Shark Bay through seeding of hatchery produced juveniles.
3. Determining feasibility of re-establishing founder population of Scallops in the Abrolhos Islands through translocations.

FRDC#2015-011 Understanding the factors contributing to decreased School Prawn productivity in Camden Haven Estuary and associated lakes, to target ameliorative actions
Principal Investigator: Matt Taylor
1. Examine School Prawn recruitment to different areas within the Camden Haven estuary, to determine if recruitment limitation in certain areas is likely.
2. Evaluate whether post-recruitment processes in Camden Haven estuary may be adversely affecting School Prawn growth and survival.
3. Synthesise research findings to provide recommendations to catchment, habitat and fishery managers regarding restoration of School Prawn productivity.

FRDC#2015-027 Examining the relationship between fishery recruitment, essential benthic habitats and environmental drivers in Exmouth Gulf
Principal Investigator: Lynda Bellchambers
1. Collate and review historical, satellite, habitat and environmental data for the Exmouth Gulf and Shark Bay ecosystems to identify factors that my influence recruitment.
2. Assess the ability of different techniques, at various spatial and temporal scales, to identify, assess and monitor critical fish habitat and environmental conditions which may affect recruitment patterns of prawns into the Exmouth Gulf Prawn Managed Fishery.
3. Collect local environmental and productivity data to assess the feasibility of collecting broad-scale data remotely.
4. Develop a cost-effective monitoring program for critical fish habitat and environmental drivers which allows the development of mitigation measures to assist in alleviating poor recruitment events.

FRDC#2015-025 Patterns of interaction between habitat and oceanographic variables affecting the connectivity and productivity of invertebrate fisheries
Principal Investigator: Daniel Ierodiaconou
1. Integrate commercial catch and survey data with LiDAR-derived seafloor structure information to identify the spatial structure and patch-level productivity of reef systems, potential Abalone fishable habitat extent and map important source reefs of Abalone larvae.
2. Development of a high-resolution hydrodynamic model for Victorian coastal waters that allows the modelling of larval dispersal between individual reef complexes throughout the state's waters.
3. Development of a biophysical larval dispersal model to map the probable dispersal pathways for *H. rubra* and SRL across Victorian reef complexes.
4. Determine if recruitment across the respective fisheries is influenced by adaptive genetic factors.

Term of Reference
(c) recent and projected changes in marine pest and diseases associated with climate change;

FRDC#2013-217 Development of management recommendations to assist in advisories around seafood safety during toxic bloom events in Gippsland Lakes
Principal Investigator: Vincent Pettigrove
1. Determine uptake, elimination and tissue distribution of nodularin in commercially and recreationally relevant species under laboratory and field conditions.
2. Review current algal bloom response plan for the Gippsland Lakes and those used in monitoring programs in Australia and around the world.
3. Provide sampling and risk management recommendations, based on scientific and research findings from objectives 1 and 2, to deal with fishing closures and re-opening during bloom events.

FRDC#2011-070 TSGA IPA: Comparative susceptibility and host responses of endemic fishes and salmonids affected by amoebic gill disease in Tasmania
Principal Investigator: Mark Adams
1. Determine the susceptibility of sea-cage associated endemic fishes to amoebic gill disease in comparison to Atlantic Salmon.
2. Investigate the comparative host responses of Atlantic Salmon and Rainbow Trout native and previously exposed to amoebic gill disease.

Term of Reference
(d) the impact of these changes on commercial fishing and aquaculture, including associated business activity and employment;

FRDC# 2014-402 Planning, developing and coordinating national/regional research, development and extension (RD&E) for Australia's recreational fishing community
Principal Investigator: Matt Barwick
1. Proactively work with the recreations fishing community to facilitate identification of national and regional RD&E priorities annually, and development of projects address those priorities.
2. Assist FRDC with management of a portfolio of projects which provide significant flow of benefit to the recreational fishing sector.
3. Continue to be a driver for the extension of R&D results to facilitate desired outcomes.
4. Facilitate co-investment in RD&E which benefits the recreational fishing community nationally.

FRDC#2014-010 Understanding recruitment collapse of juvenile Abalone in the Eastern Zone Abalone fishery – development of pre-recruitment monitoring, simulation of recruitment variation and predicting the impact of climate variation
Principal Investigator: Craig Mundy
1. Optimise collector module design for quantifying abundance of juvenile Abalone across a range of habitat types.
2. Determine links between juvenile abundance observed on modules and Abalone in surrounding habitat.
3. Estimate expected juvenile abundance on collectors in a ‘normal’ recruitment year using published natural mortality data and known abundance.

Term of Reference
(e) the impact of these changes on recreational fishing;

FRDC#2014-005 The application, needs, costs and benefits of Habitat Enhancement Structures in Western Australia and cost effective monitoring methods
Principal Investigator: Andrew Rowland
1. Identify what HES are currently available throughout the world and what benefits each type may have for recreational and commercial fishing as well as identifying the benefits for aquaculture and the environment.
2. Identify how various HES design might provide benefit to the WA seafood sector and community and determine applications and locations for the most effective return on investments.
3. Determine cost-effective methods to monitor HES developments using easily available materials and data collection by community and industry groups.
4. Investigate cost-effective reef, site selection, approvals, construction, deployment and monitoring strategies for business, industry and community groups wanting invest in HES.

FRDC#2013-205 Beyond engagement: moving towards a co-management model for recreational fishing in South Australia
Principal Investigator: Keith Rowling
1. Identify, document and evaluate fisheries co-management models for recreational fishing across Australia.
2. Develop an appropriate and effective co-management model for recreational fishing in South Australia.
3. Conduct a case study to evaluate the success of the most appropriate management model(s) for co-management of recreational fishing.
4. Develop tools for co-management of recreational fishing utilising information from the case study, and apply these tools by formalising the relationships through an agreement with the Fisheries Council of South Australia.

Term of Reference
(f) the adequacy of current quota-setting and access rights provisions and processes given current and projected climate change impacts;

FRDC#2014-023 An industry based mark recapture program to provide stock assessment inputs for the Western Rock Lobster Fishery following introduction of quota management
Principal Investigator: Simon de Lestang
1. Determine spatially specific exploitation rates and legal biomass levels.
2. Increase precision of estimates for movement rates between management zones.
3. Improve understanding of the variability of growth throughout the range of the fishery.

FRDC#2014-008 Fishery status reports: health-check for Australian fisheries
Principal Investigator: Alistair Hobday
1. In consultation with fisheries stakeholders identify a broad range of criteria for reporting the status of Australian fisheries.
2. Develop a web-based and summary template for reporting the status of Australian fisheries across a range of criteria.
3. To illustrate this approach, undertake several case studies on selected fisheries.
4. Develop a pathway for linking these fishery-level reports with the stock status reports (SAFS) and handing over methods to appropriate jurisdictions for implementing the reports into the future.

FRDC#2013-210 Adapt or Fail: Risk management and business resilience in Queensland commercial fisheries
Principal Investigator: Renae Tobin
1. Document the current diversity and develop typologies of business models and operation types employed across all commercial fisheries on Queensland’s east coast.
2. Explore the current adaptation options for different business model types regarding risks associated with economic, management and environmental changes.
3. Document the common constraints affecting uptake of adaptation options between and across business model types.
4. Provide information tools regarding adaptation options for different business model types to fishers and managers, to enable the improvement of adaptive capacity and hence resilience.

FRDC#2009-211 Whose fish is it anyway? – Investigation of co-management and self-governance solutions to local issues in Queensland's inshore fisheries
Principal Investigator: Daryl McPhee
1. Trial the implementation of a locally based co-management approach in three areas.
2. Empirically assess the local socio-economic environment as it pertains to the fishery and identify the various tools that may be applied to local management issues.
3. Assess the applicability of the identified management tools to each local circumstance, and the socio-economic cost and benefits of their application.
4. Develop appropriate proposals for local area fisheries management and identify the pathways and timeframes necessary to implement them.

FRDC#2012-024 INFORMD Stage 2: Risk-based tools supporting consultation, planning and adaptive management for aquaculture and other multiple-uses of the coastal waters of southern Tasmania
Principal Investigator: Scott Condie
1. For the marine environment of southern Tasmania, characterise key environmental, social and economic values and aspirations from industry, government and community perspectives.
2. Relate these values to measurable indicators based on understanding of key biophysical and socio-economic processes.
3. Develop a framework to support spatial risk assessment for planning of future development within the system, with an initial focus on aquaculture leases.
4. Develop a framework for evaluating spatial risk-management strategies, with an initial focus on managing aquaculture leases.
5. Integrate the planning framework (objective 3) and risk-management framework (objective 4) into an online tool accessible to key stakeholders.

FRDC#2011-030 Evaluating candidate monitoring strategies, assessment procedures and harvest control rules in the spatially complex Queensland Coral Reef finfish Fishery
Principal Investigator: Richard Little
1. To give scientists and managers in DEEDI their own ability to compare and contrast methods of data collection and analysis for the CRFFF, in order to aid the identification of appropriate harvest strategies.
2. To update the economic and fisheries data used to determine cost-effective management strategies.
3. To identify appropriate spatial and temporal fishery-independent and fishery-dependent monitoring strategies, and assessment and harvest control rules that use them.

Terms of Reference
(g) the adequacy of current and proposed marine biodiversity protections given current and projected climate change impacts;
(h) the adequacy of biosecurity measures and monitoring systems given current and projected climate change impacts;

FRDC# 2014-224 Rebuilding Abalone populations to limit impacts of the spread of urchins, Abalone viral ganglioneuritis and other external impacts
Principal Investigator: Harry Peters
1. Identify and prioritise sites and strategies for assessment to recover shallow reef habitat and productive Abalone populations.
2. Assess strategies for recovery of shallow reef habitats and productive Abalone populations.
3. Develop a business plan to guide ongoing future actions and strategies to extend the project outputs and rebuild Abalone populations.

FRDC#2015-040 ABFA IPA: an assessment of the risk of exotic disease introduction and spread among Australian Barramundi farms from the importation of Barramundi products
Principal Investigator: Marta Hernandez Jover
1. Identify biological hazards, described as pathogens causing infectious diseases that could enter Australia with imported *Lates calcarifer* products.
2. Identify pathways of pathogen entry into Australia (entry assessment) and estimate the likelihood of these pathways to occur.
3. Identify pathways of Barramundi in Australia (including aquaculture and importantly includes wild harvest, recreational and indigenous sectors) being exposed with the pathogens released into the country from imported *Lates calcarifer* products (exposure assessment) and estimate the likelihood of these pathways to occur.
4. Describe the potential spread scenarios after the first Barramundi sector of the industry has been exposed with the pathogens of interest, estimate the likelihood of these scenarios to occur and describe direct and indirect impacts (consequence assessment).

FRDC#2015-406 Oysters Australia IPA: development of a national Pacific Oyster Mortality Syndrome (POMS) response plan
Principal Investigator: Jan Davis
1. To develop a national POMs response plan.

FRDC#2014-040 Oysters Australia IPA: Pacific Oyster Mortality Syndrome (POMS) – closing knowledge gaps to continue farming *C. gigas* in Australia
Principal Investigator: Richard Whittington
1. To determine methods for the conditioning/husbandry of spat and juvenile Oysters to obtain survival after exposure to OsHV-1 based on improved scientific understanding of exposure, pathogenesis, immunity, tolerance or latency.
2. To confirm a) the consistency of seasonal patterns of POMS, b) the periodicity of infection within season, c) inter-estuary temperature variation, and d) predict POMS seasonal behaviour.
3. To identify changes in OsHV-1 DNA sequence over time (2010–2016) to understand infection and disease patterns.
4. To investigate the mechanisms of survival of Pacific Oysters after exposure to OsHV-1, including assessment of exposure dose and using biosensors.
5. To determine whether water treatments prevent OsHV-1 infection of spat or merely prevent mortality, and whether they can be applied for biosecurity of hatchery effluent.
6. To describe an integrated disease control strategy based on complementary use of genetically resistant Oysters (when available) and husbandry methods throughout the production cycle: hatchery-juvenile grow-out to market.
7. To build capacity in aquatic animal health for Australian industry through training a post graduate student.

FRDC#2015-239 Oysters Australia IPA: Pacific Oyster Mortality Syndrome – resistant Oyster breeding for a sustainable Pacific Oyster Industry in Australia
Principal Investigator: Matthew Cunningham
1. To achieve genetic gains in POMS resistance in the ASI population by 14% per year.
2. To commercialise the most resistant ASI families to improve commercial viability of Pacific Oyster growers in Australia. Broodstock with a predicted survival as 1 year old animals of 80% commercially available by the end of the project.
3. Support industry peak bodies in their consideration of mechanisms for emergency response arrangements.

8 – Acknowledgements

This submission was prepared for FRDC by Colin Creighton (colinmwnrm@bigpond.com) in consultation with FRDC, Department of Agriculture and Water and Australian Fisheries Management Authority staff and in discussion with industry, researchers and fisheries managers from across Australia.