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CONSULTING

Climate Change and Australian Fisheries

Knowledge imperatives and research opportunities

Report for the Fisheries Research & Development Corporation (FRDC)

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Disclaimer

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Climate Change and Australian Fisheries

Knowledge imperatives and research opportunities

PURPOSE

To review the knowledge base for the potential impacts of climate change on Australian fisheries and to outline options for improving it.

RECOMMENDATIONS

1. That all jurisdictions agree to a national R&D program aiming to assist Australian fisheries to anticipate, respond to and manage the impacts of climate change, as outlined in broad terms at Attachment A.
2. That the FRDC commission a scoping study to flesh out research priorities as outlined at Attachment B.

BACKGROUND

Limited research work has been done, nor is much underway, directed to improving understanding of the impacts of climate change on Australian fisheries and the capacity of industries and governments to manage those impacts. This paper outlines measures that would substantially improve that capacity (Attachment A). Research priorities are set out in more detail at Attachment B. An initial investment of around $10m over five years would generate substantial co-investment, building on the substantial achievements of recent years in structural reform to improve the sustainability of Australian fisheries. It would be a critical insurance premium for a $5 billion sector of the economy, comprising its commercial marine, aquaculture, recreational and indigenous fisheries. These sectors are likely to be affected by climate change in different ways, as are the different coastal regions around the continent in which more than 85% of the population resides and much critical infrastructure is located.

DISCUSSION

Climate variability has long been a significant factor affecting many Australian fisheries. That inherent variability is becoming accentuated by an underlying directional change in climate, beyond natural bounds of variability, attributed to human activity altering the composition of the atmosphere. Climate change is already affecting Australian marine life and consequently Australian fisheries and aquaculture (Newton 2007). These impacts have been analysed comprehensively in two recent reviews commissioned by the Australian Greenhouse Office (Hobday et al 2006, Hobday and Matear (eds) 2005). The types of environmental variables likely to be driven by a warming climate include changes in temperature, ocean currents and chemistry (predominantly acidification), winds, nutrient supply, river run off, sea levels, rainfall and extreme weather. These are expanded in Table 1 below. These in turn are likely to affect key biological attributes of commercially important species and ecosystems including phenology and physiology; range and distribution; composition and interactions within communities; and structure and dynamics of communities (Hobday and Matear 2005).

There are already clear indicators in several significant fisheries of changes occurring in response to these environmental variables, although work to date has concentrated on range and distribution. Examples include:

- the invasion off the east coast of Tasmania of sea urchins native to NSW has caused barrens (loss of kelp and reduced diversity);
- an increasing proportion of tropical species in phytoplankton blooms off Tasmania;
- the rock lobster catch and distribution is correlated with changing sea surface temperatures (SST) around the Tasman sea;
- in the last decade 34 fish species have exhibited major distributional changes – significant range extensions or newly established south of Bass Strait.

The aggregate impact of climate change on Australian fisheries appears likely to be very large indeed. Not all of those impacts will be negative, and it is critical to identify opportunities as well as threats. Significant positive spillovers into other sectors such as tourism, agriculture and water management will potentially emerge from climate change understanding, adaptation and risk management strategies in Australian fisheries and aquaculture.

In order to develop appropriate policy and management responses in government and industry, it is necessary to disaggregate potential impacts region by region and fishery by fishery. There is no doubt that more research is needed. Current knowledge is very patchy, especially at finer grained levels of analysis. Impact research is critical, but is useful only up to a point. We must go beyond the articulation of potential impacts, to develop tools that can assist policy makers, regulators and industries to design and implement measures to capture opportunities generated by climate change, to manage the risks inherent in climate change, and to minimise negative impacts – economic, social and environmental.

Such tools would be an important complement to the critical structural reforms in Australian fisheries over recent years, and fit easily within Australia's Ecosystem Based Fisheries Management approach. They would also complement other recent strategic investments, including the improved ocean predicting capability through BlueLink (Navy and CSIRO) and the Integrated Marine Observing System established with a $55m investment through the National Collaborative Research Infrastructure Strategy (NCRIS).

In developing capacity to anticipate and manage climate change impacts more strategically, the fisheries sector can learn from experiences in Australian agriculture. Agricultural industries have been investing in climate research since 1992, with the advent of the Climate Variability in Agriculture Program jointly funded by most of the rural Research and Development Corporations (RDCs), and now called Managing Climate Variability. That program has now blurred the distinction between climate variability and climate change, and has developed a range of applied tools to assist land and water managers to understand their climate risk, to map the key climate-dependent decision points in their business, and to develop pro-active approaches to managing climate risk. It has also produced a range of useful communication products, including the Masters of Climate case study series of 40 farm businesses at the leading edge in applying climate science within their business.

The National Agriculture and Climate Change Action Plan 2006-2009 has been agreed by all Australian jurisdictions, with strong support from the NFF. It sets out a framework for anticipating and responding to climate change, in four key areas: Adaptation; Mitigation; Research and Development; and Awareness and Communication. This framework helps to refine knowledge needs and to ensure a receptive environment for research outputs that meet those needs. The policy, management and research domains should inform each other, rather than developing independently in isolation from each other.

Several lessons can be drawn from this experience. In order to get beyond the development of impact scenarios and into proactive risk management, and strategic – as opposed to reactive – policy, regulatory and management responses, several key ingredients need to be in place:

- Firstly, the knowledge base needs to be sufficiently broad and deep (this does not imply complete knowledge) on which to build good policy and clever management responses;
- Secondly, the policy and management communities (in this case relevant State and Commonwealth agencies, leading fishing industry representatives and opinion leaders within each sector) need to be involved from the outset in filling any gaps in that knowledge base, framing the research questions and actively engaged in the enquiry process;
- Thirdly, better research outcomes are more likely if the key end-users are engaged in parallel processes of, for example policy development, regulatory reform, industry-level best-practice improvement and so on. Such activities exert a 'user-pull' on the research process.

- Fourthly, it is necessary when dealing with large, complex issues such as climate change, characterised by a massive basic and strategic basic research effort in areas like climatology and oceanography, to deliberately exert an applied research demand to translate fundamental understanding into practical and pragmatic management tools and policy responses. In some cases this can mean developing new researchers who can take the outputs of, for example, the next generation of global circulation models, and from these develop applications attuned to the decisions that need to be made by governments and industries.

In the agricultural sector, it was mainly through the influence of the Managing Climate Variability program and its predecessors, that the climate science community was encouraged and assisted to develop more applied seasonal forecasting tools. Applications such as *SILO, RainMan, RainMan Streamflow, AUSSIE GRASS* and *YieldProphet* are now widely used by leading farmers and advisers. Moreover the new science capacity in these more applied areas developed through those investments is now highly valued within agriculture. An independent evaluation of that program (Schofield 2005) using conservative assumptions and measuring only quantifiable benefits found that it delivered an internal rate of return in excess of 28% and a benefit/cost ratio of 4.7:1 for a net present value in excess of $350M.

Table 1: Some likely impacts of climate change on Australia's coasts and oceans, as exemplified by some biophysical change from climate drivers (CSIRO Marine and Atmospheric Research; Bureau of Meteorology; Australian Greenhouse Office).

	Likely bio-physical change from climate change drivers
Sea level rise and storms	• a rise in sea-level from thermal expansion of the ocean and glacial melt, and increased frequency or intensity of extreme storms - leading to higher risk of inundation and flooding. • shoreline erosion and realignment leading to loss of amenity or damage to assets (natural and human).
Warmer ocean temperatures	• increased frequency of coral bleaching events (present models project the Great Barrier Reef will warm by 2 to 5° C by 2100). • potential impacts on biodiversity by affecting the distribution and reproductive patterns of marine organisms, and consequently food web dynamics (productivity).
Ocean acidification	• increased CO_2 concentration in sea water is altering ocean chemistry, making it more difficult for calcitic organisms such as coccolithophores, corals and molluscs to grow and function.
Tropical cyclones and storm surges	• combined with higher sea levels, the projected increase in frequency and intensity of tropical cyclones would cause more frequent and intense coastal flooding. • tropical cyclones may occur further south than they do at present. • there are likely to be shifts in prevailing wind and wave climates.
Decreased rainfall & drought	• warmer temperatures will cause greater evaporation, increasing the severity of drought for a given decrease in rainfall.
Run-off changes	• changes in climate over land will cause changes in run-off reaching coastal and marine systems and alter the availability and quality of freshwater - this has implications for productivity and ecosystem function of coastal and estuarine environments. • related changes in riverine flooding frequency and intensity.
Ocean stability and currents	• changes to wind and water temperature affect water column stratification and stability – leading to changes in upwelling of nutrient rich deeper waters and productivity of surface waters. • Changes to ocean currents, notably the East Australian and Leeuwin currents, may affect dispersal and distribution patterns of marine organisms
ENSO	• some models suggest global warming may lead to an increase in the frequency or intensity of El Nino events - if so, Australia may have more intense droughts and La Nina floods, particularly in the eastern part of the country.
Increased fire and wind	• increased frequency and/or intensity of aeolian dust and fire-born particulates can affect coastal productivity and promote blooms.

A national climate change and fisheries R&D program

Design principles

From these points, and drawing on experience from agriculture, it follows that some design principles for an effective engagement with climate science by Australian fisheries sector include:

- Research is likely to be better targeted if it takes place in parallel with and complements a related policy framework (e.g. the National Climate Change Action Plan for Australian Agriculture signed off by all jurisdictions with strong support from NFF). That framework can also outline industry priorities and strategic directions in response to the climate threat. Hobday and Matear (2005) note that *"Australian fisheries and aquaculture management policies do not currently incorporate the effects of climate variability or climate change in setting harvest levels or developing future strategies."*
- Knowledge gaps and research priorities need to be teased out jointly by researchers, research managers, fishers, policy makers and regulators.
- Fisheries-specific applied climate change research expertise is so limited, and the momentum of the broader climate change research effort so strong, that the arguments for a single national research program in this area are compelling. This would make best use of scarce resources (both funds and researchers); avoid duplication of effort; develop common cross-jurisdictional understanding; exert a concerted demand-pull on the climate science effort to get outputs tailored to the needs of fisheries; develop fisheries-specific climate change research capacity; and present a cohesive conduit to this research for industry and government players.
- An applied R&D program such as this, needs to be driven and managed from a fisheries industry and policy perspective, informed by climate science but not driven by it.
- The uncertainties inherent in climate science and the pervasive and profound nature of its potential impacts, mean that research is more likely to be influential if it is as participatory as is practicable in engaging target audiences throughout the inquiry process. A multifaceted communication effort should be built-in from day one, not retrofitted at the end when the budget has been spent.

Research priorities

The National Climate Change Action Plan for Australian Agriculture is based on a framework of four key elements: Mitigation, Adaptation, Communication and R&D. This is an appropriate policy framework, against which research priorities for agriculture can be developed relatively easily. Agriculture is the second biggest source of Australian greenhouse gas emissions behind stationary energy (power stations), so it is desirable for agriculture to have mitigation as a significant plank in its climate change platform. The impact of fisheries on emissions is less significant, although the energy-intensiveness of the sector is high in terms of energy consumed per unit output. Energy efficiency measures in the harvesting and processing of wild catch fisheries, and throughout the production process in aquaculture, are valid sustainability options. However any fisheries-oriented policy framework for climate change is likely to underline anticipation, adaptation and risk management as its key elements.

The content knowledge needed to implement such a framework is summarised in Attachment B.

Research management

The following table draws on the discussion of research priorities at Attachment B. It outlines a possible research program structure and some of the key (not necessarily the only) disciplines that would need to be involved. The areas of research focus are defined here only in the broadest terms and would need to be refined in a more detailed scoping study in consultation with all sectors of the industry, building on the reviews done by Hobday & Matear (2005) and Hobday et al (2006).

Theme or sub-program	Research focus	Necessary disciplines
Ecological impacts	Understanding climatic influences on aquatic biota and the potential biological & physical impacts of climate change by region and fishery. Monitoring shifts in distribution and phenology (e.g. migration, reproduction)	Climate modellers, fisheries and aquaculture scientists, fishers, ecologists, oceanographers
Social and economic impacts	Understanding the social and economic impacts of climate change on Australian fisheries (including recreational and indigenous fisheries) and the spillovers in Australian communities and the wider economy. Assessing the potential impact of options developed in the themes below.	Fisheries managers and policy makers, political scientists, social scientists (e.g. impact assessment), human geographers, economists
Adaptation strategies (including risk management)	Anticipating climate impacts (tools that help fishers and fishery managers to use outputs from climate models in decision making); developing scenarios; identifying adaptation options; sensitivity and vulnerability analyses; determining trigger points and thresholds for ecosystems and industries; evaluating risk and developing adaptation and risk management strategies.	Fisheries and aquaculture scientists, modellers, fishers, fisheries managers, risk management consultants, economists, knowledge brokers
Policy, Management and Governance	Analysing current and potential policy, regulatory and management frameworks against a range of scenarios; sensitivity and vulnerability analyses; determining trigger points and thresholds for policies; reviewing developments in other sectors; developing and evaluating new frameworks.	Fisheries managers and policy makers, political scientists, environmental lawyers, economists
Mitigation	Reducing greenhouse gas emissions from aquaculture and fisheries (integrated with energy efficiency work in other industries)	Fishers, fishery managers, engineers, economists, sustainability consultants

It is clear from this table that the multifaceted challenges – and potential opportunities - presented by climate change require inputs from a wide range of scientific disciplines working together, or at least within research and knowledge management frameworks that enable the bringing together of diverse perspectives and types of knowledge. In some instances it is appropriate for researchers from different disciplines to be combined within projects in multi-, inter- or trans-disciplinary research – in others it suffices for tightly focused uni-disciplinary projects to be brought together within a larger theme or sub-program.

It is also clear from this table and the foregoing design principles that the research process will need to be highly collaborative, involving researchers, policy makers, fishers, fishery managers and all components across the fisheries sector – and in many cases across jurisdictional boundaries. In the words of Frank Greenhalgh from Fisheries Victoria (*pers comm*): *"This area of research provides a real opportunity for FRDC to commission large collaborative projects to most efficiently and effectively utilise research resources to produce relevant information for use by fishery managers and industry, and hence make significant contributions to outcomes for Governments, the community and fishing industries."*

In terms of resources, and drawing on the example of the Managing Climate Variability Program in agriculture, such a research agenda would require a minimum investment of $2 million in cash per annum from the Australian Government for at least five years to be viable. That investment would likely be at least doubled in cash terms and doubled again in-kind through co-investment from partners and industry — generating a total investment in the order of $40 million.

This would be a prudent, modest investment on a serious issue affecting a five billion dollar industry (counting recreational and tourism dimensions of the fisheries sector). Given the importance of the oceans as drivers of Australia's climate, it seems likely that applied research in this area will not just benefit fisheries, but will have significant spillover benefits including for marine tourism, infrastructure and coastal planning, agriculture and water management. The return on investment is likely to be comparable to the 28% internal rate of return and 4.7:1 benefit:cost ratio achieved by the Managing Climate Variability Program.

Knowledge and adoption

Achieving such a return from an investment in research depends crucially on the level of adoption of research outputs. It doesn't matter how good the research is if nobody is using it.

Climate change is a classic issue to which effective responses are likely to demand systemic reform and changes in understanding and behaviour at all levels, yet technical issues are likely to remain complex and subject to a degree of uncertainty.

In such contexts, it is critical to design into the applied research process a serious knowledge and adoption strategy — a carefully thought through approach to capture the knowledge assets generated through the program and to actively manage those assets through learning processes that maximise prospects for widespread adoption (Campbell & Schofield 2007). This strategy must be developed in parallel with the research plan from day one, and is likely to affect every other aspect of the program, from overall governance to the design of individual projects and the framing of research questions. The adoption plan for fishers is likely to differ from the adoption plan for policy makers, or fisheries managers, or recreational fishers, or indigenous communities and so on. It means much more than just 'communication', which usually defaults to passive, one way, one off dissemination of research findings after the inquiry process has run its course and moved on.

If the Australian fisheries sector is to get its collective head around climate change and its implications, then it needs a broad cross section of the industry to be involved in consolidating the knowledge base and sharing the lessons learned and ideas generated. The base knowledge, the synthesis products (publications, manuals, workshops, courses etc), the key expertise and any emerging areas of innovation need to be widely and freely accessible through multiple, easily searchable gateways. A good knowledge and adoption plan can design the framework for such a learning system that will maximise the return on research investment.

Governance

Large, collaborative, inter-disciplinary research investments involving multiple jurisdictions, industry sectors, and participants from policy makers to practitioners, demand good governance.

Such governance is easier to establish on a foundation of relationships of good standing and goodwill between the key players. A useful principle for collaborative R&D governance is that the governance structure (board, management committee or whatever) needs to involve the investors, and that it needs to be separate from day to day research management. Such disciplines are easier to establish and maintain against the background of an R&D plan agreed by the investors, and some form of program management agreement (signed off by the investors) that sets out the respective roles and responsibilities of the investors and their managing agent (Campbell and Schofield 2007).

Equally, research investments like this one require dedicated, professional management — both in terms of robust systems and expert people with industry credibility. The fisheries sector already has a dedicated, credible research investment and management agency in the form of the FRDC that is well placed to deliver such a national collaborative program.

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ATTACHMENT B

A national climate change and fisheries R&D program

Research Priorities

Hobday and Matear (2005) review the science on climate change impacts on Australian fisheries and aquaculture. They note that the base knowledge for exploring such impacts (actual and potential) is an understanding of the relationships between climate and aquatic biota, and that this knowledge base in the Australian context is thin, patchy and recent. Spatial and temporal information on a range of species (current commercial species, trophically-linked species and ecosystem indicators) is necessary for baseline information and to track changes. There is neither the time nor the resources however to undertake comprehensive baseline studies of all relevant species in all regions. Retrospective analyses using existing long term data sets remain important, and emerging ocean models can make up for some data gaps. However it is clear that the research effort needs to focus on some key priorities.

Hobday and Matear (2005), noting research already underway in fisheries such as the Northern Prawn and the Eastern Tuna and Billfish Fishery, suggest that the best return on immediate additional research investment on ecological relationships can be gained by focused studies of climate change impacts on:

- South-east demersal fisheries, where relatively rapid warming is already apparent.
- Western rock lobster, to unpack the linkages between recruitment and later harvests, and the potential impacts of climate change on these linkages.
- Changes in productivity around Australia influenced by for example changes in upwelling and mixing, to forecast changes from the base of the food chain, including opportunities.

While fundamental ecological understanding of climatic impacts on biotic relationships is a necessary condition for developing a decent climate change strategy for Australian fisheries, it is not sufficient. Climate is an important factor influencing the sustainability of Australian fisheries, but far from the only one. Getting the management regime right, in particular the overall fishing effort, remains more important for most if not all Australian fisheries. Adaptation-oriented research supporting fisheries management is required to answer questions such as whether the current baselines that underpin management regimes may change, and if so, in what direction, and to what degree.

Adaptation-oriented research is also required to develop new options for industry, for example temperature tolerant strains of fish for aquaculture and stock enhancement, and potential opportunities to utilise other fisheries. Fisheries managers see possibly more scope for adaptation strategies in aquaculture than in wild catch fisheries. Risk management is a critical adaptation strategy but is also an area for research in its own right. Scenarios can also be used to explore the potential social and economic impacts of different uses of fisheries resources. Hobday and Matear (2005) suggest that social and economic impacts of climate on fisheries and aquaculture could be explored through regional focus studies, for example on the Western Tuna and Billfish Fishery, and on salmon farming aquaculture. International studies would also be required to ascertain the potential impacts of global concern about climate change on the demand for Australian fisheries exports (and possibly on supply from competitors).

There appears to be considerable scope to use the oceanographic work to develop scenarios that could be used in participatory research involving fisheries managers to evaluate the robustness of existing management structures and governance regimes in key fisheries. Such research could also explore potential biosecurity risks and the implications of a range of climate change scenarios for intra- and inter-sectoral allocation triggers. Sensitivity analyses could assist in identifying the types of information that are most crucial on which to base management responses, and the degree of spatial and temporal precision required.

In summary, desirable themes in any national Climate Change and Australian Fisheries R&D Program would include: climate change impacts on marine life; adaptation strategies; management and governance regimes; social and economic impacts; and mitigation.

Mitigation work in fisheries, such as energy efficiency measures, could 'piggy-back' on similar exercises in other primary industries. For example, fisheries shares with horticulture and meat many of the same issues in downstream transport, processing and storage using refrigerated facilities. It shares with broadacre agriculture many of the same issues around the efficiency of diesel engines and potential opportunities to move to biofuels. One of the most urgent research priorities in this area is the need to develop user-friendly carbon accounting tools that the fishing industry can use to determine and analyse its own greenhouse gas emissions 'footprint' across the whole sector. Again, there would be considerable opportunities to co-invest in such work with other sectors in horticulture and agriculture.