Indian Ocean Climate Initiative

Informed Adaptation

Living With Our Changing Climate:

Report of Workshop, 17 August 2005

Establishing key impacts of and responses to our variable and changing climate in the south-west of Western Australia, and the future role of research by the Indian Ocean Climate Initiative.

Editors
Miles Dracup, Richard McKellar and Brian Ryan
December 2005

Workshop sponsored by the Australian Greenhouse Office and CSIRO Climate Program

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Australian Government
Department of the Environment and Heritage
Australian Greenhouse Office

CSIRO

The Indian Ocean Climate Initiative (IOCI) is a partnership of the State Government of Western Australia, CSIRO and the Australian Bureau of Meteorology, which was formed by the Western Australian Government to support informed decision making on climate variability and change in Western Australia.

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Please see Appendix B

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Foreword

The climate of Western Australia's south-west is changing. There has already been a consistent increase in temperature, and a less consistent, though arguably more concerning, decrease in rainfall and runoff, particularly since the mid 1970s. Rainfall has decreased more in some seasons (especially May to July) than others, and in some areas more than others. Average annual rainfall has decreased by up to 30 per cent, and the 15 per cent reduction in western areas has reduced dam inflows by more than half. These warming and drying trends are projected to continue.

Recent climate changes have already affected some government and private decisions. The reduction in rainfall has had major implications for the security of water supply with resultant impacts on water supply investment and management. The implications for other sectors are less clear, but appear to be potentially significant. The depth and maturity of understanding and consideration of trends, impacts and responses to climate variability and change, varies between sectors.

A workshop held on 17 August 2005 drew on the science and knowledge shared at the preceding two-day IOCI seminar Living with our Changing Climate. The workshop brought together invited representatives from key sectors affected by climate change and climate scientists, and sought to identify:

1. key impacts of the south-west's variable and changing climate on the represented sectors;
2. responses already made by those sectors;
3. key future responses likely to be required;
4. climate and sectoral research priorities; and
5. linkages between sectors or other groups to facilitate effective responses.

While the focus of the workshop was on living with our changing climate in the south-west of WA, some of the issues had State-wide relevance.

This report presents the views of workshop participants, which may not necessarily be those of their affiliated organisations.

Information gleaned from the workshop will be used in designing further stages of the IOCI research program and in the Australian Greenhouse Office-sponsored project to address Action 5.5 of the WA Greenhouse Strategy, which explores the vulnerability of south-west WA to climate change.

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Executive summary

Climate changes in the south-west of WA since 1970 have generated a variety of impacts and responses across sectors.

- Reduced rainfall has affected agriculture, forestry, biodiversity, and water tables and supplies. Direct impacts include lower soil water availability for agricultural and tree crops and forests, reduced waterlogging, and reduced surface and ground water availability. Managed systems, such as agriculture, forestry and water supplies, have responded by developing new technologies or products to improve water use efficiency, new information and decision systems for managing rainfall variability, increased investment in water related infrastructure, water demand management initiatives and policy and legislative developments to support efficient water allocation. Self-adapting systems, such as ecological systems or quasi-managed systems, have responded by changing their composition, locality, or structure. To date there have been no overt impacts on health, infrastructure or industry.
- No terrestrial impacts specifically from increased temperatures were reported as having been observed. However, higher air temperatures can exacerbate decreases in soil moisture.
- Marine and coastal environments have experienced increasing sea surface temperatures and higher sea levels, increasing acidity and changing ocean energetics. Few direct impacts have been ascribed to these changes so far.

Future climate change is expected to result in further temperature increases and reductions in rainfall in much of the south-west of WA, necessitating key adaptive responses, such as:

- Greater efficiency of water use and reuse and more responsive, flexible and transparent water allocation mechanisms. This will involve new technologies, practices and policies, and greater public awareness. Greater institutional, public and stakeholder capacity for information management, stakeholder involvement, conflict management and management of property rights and market mechanisms will be required.
- Managers of agricultural, forestry and water systems will seek to project the implications of climate changes for relevant time periods and areas – relating to the viability of agricultural enterprises, plantation life cycles and infrastructure – and plan accordingly. New crop types and technologies are likely to be required, along with more diverse water supplies and improved demand management.
- Biodiversity and hydrology systems will require better understanding of underlying system processes and interactions with or dependence on climate parameters such as temperature and rainfall, and major variations to the extremes, such as heat waves, drought periods and heavy rainfalls. The complexity of the systems makes direct management of climate change impacts more challenging, raising the need for prudent planning and risk assessment and management.
- Sectors such as health, infrastructure, insurance and industry need to develop information and policy systems that ensure well-informed adaptation to climate variability and change. This will involve a range of initiatives, including research, information management and communication, decision frameworks and principles, partnerships and coalitions. Particularly vulnerable groups or sectors will need greater attention.
- Ongoing increases in ocean temperatures and acidity, rising sea levels and changes in ocean circulation pattens will inevitably impact on marine ecosystems and shorelines and probably ocean currents. Experience elsewhere, including on Australia's east coast, suggests that State-wide impacts such as coral bleaching and death, coastal erosion, changes to fish abundance and distribution, and changes to coastal ecosystems are likely.

To underpin informed responses to climate variability and change, more localised and credible projections of future climate are needed. The projections should include seasonal variability and extreme events such as heavy rainfall, high winds, hail, frost, drought, extended hot periods, storms and lightning. In addition, some key gaps need to be filled to effectively explore implications and scenarios for sectors and prospective responses, including:

- Understanding interactions between climate and ecosystem composition, structure and function, and how changes in climate might affect ecosystems. Better baseline information on system condition and performance is also needed for projecting future impacts. Better knowledge will also be required about potential indirect impacts, such as the invasion and spread of human, agricultural or ecological pests and diseases.
- Better social science capacity will be required, including the analysis of climate change consequences with and without intervention and decision-making under uncertainty.
- Three enabling environments will be required: a policy environment that is able to include climate as a changing factor, institutional environments that are responsive to climate as it evolves and are able to efficiently reallocate resources as required, and public and stakeholder environments that encourage responsible involvement in policy and other decisions.

Analysis of interactions between sectors indicated that some sectors, particularly water resources, are important to all other sectors. Good information about these key sectors and carefully-developed frameworks and processes for allocation decisions will be needed along with greater conflict management expertise to resolve intra- and inter-sectoral conflicts over resource allocation.

The future of IOCI – management and linkages:

- Existing links between State Government agencies and Commonwealth Government entities such as the Australian Greenhouse Office (AGO), CSIRO and Bureau of Meteorology (BoM) are highly effective for strengthening the research-policy-program partnerships, for which IOCI was designed.
- IOCI will require sufficient financial and institutional stability to support an ongoing climate science research and communication program, and sufficient partner involvement to ensure IOCI delivers scientifically relevant information to its clients and industry.
- Collaboration and communication between IOCI and industry and the community, particularly those who need climate information for decision making, will be important to realising the full benefits of IOCI's research.
- IOCI needs to expand its underpinning science portfolio to include the whole of WA.
- IOCI could benefit from alliances with similar science initiatives in WA, such as the West Australian Marine Science Institutions (WAMSI) and closer relationships with WA university research programs. Alliances with similar initiatives in other Australian states, such as the South Eastern Australian Climate Program (SEACP), could be beneficial if they did not threaten IOCI's WA-focus, independence and identity.

1. Sector impacts and responses

The following tables identify, by sector, key impacts of climate variability and change and current and future responses to those impacts.

Key impacts	Key current responses	Key future responses
Agriculture and forestry		
Change in potential productivity of crops and plantations	• Changes in cropping technology. • Changes to crop varieties. • Increased attention to risk management and insurance. • More intensive plantation management. • Research on responses to climate variables. • Opportunistic cropping based on seasonal conditions. • Research on seasonal forecasting and modelling input responses to climate variables.	• Use of new or different species. • Changes in the geographic range of specific crops, plantations and enterprises. • Development of alternative land management and land uses.
Water supply	• Competition for water between plantations and agriculture (e.g. Gnangara mound). • Greater focus on increasing efficiency of water use. • Increased investment in water security. • Increased ground water monitoring. • Thinning of plantations.	• Diversify farm water supplies. • Increased regulation of groundwater and surface water use (especially for irrigation). • Removal of plantations. • Water trading.
Pest and disease	• Increased monitoring and surveillance.	• Use of different species for adaptation. • Research on pest and disease responses to climate change and control technology.
Insurance costs/risk; loans	• Decrease in availability of insurance. • Diversify varieties and enterprises. • Increase emphasis on risk management.	• Development of alternative agricultural industries.
Risk on capital and operating investments	• Reduced investment in rural industries. • Increased farm size.	• Reduced capitalisation. • Risk sharing approaches.
International competition		• Identify changes in relative competitiveness, markets and market demands.
Consumer attitudes	• Changed attitude to use of treated waste water for irrigation.	
Salinity spread and severity	• Salt intrusion in Swan Coastal Plain. • Declining water tables.	• Reduced rate of spread of salinity. • Improved use of water from private bores.
Fire	• Increased burning programs. • Increased emergency expenditure.	• Increase in education programs.

Key impacts	Key current responses	Key future responses
Water		
Reduced reliability of water supply (public).	• Water use restrictions. • Development of new sources, e.g. sea water desalination. • Demand management. • Water trading. • R&D to improve understanding of future supply scenarios. • R&D on catchment management to improve water yield. • Switching to private supply sources. • Competition for water. • Industry water use efficiencies publicised. • R&D on aquifer recharge using treated wastewater. • Abatement of greenhouse gas emissions.	• Increasing political and community involvement, including greater public participation on allocation process. • More water efficiency, re-use & recycling. • Water allocation – R&D on needs, transparent decision making, optimisation process, mechanisms to share the risks from variability and change between uses. • Catchment management – R&D, transparency in balancing competing demands. • Evaporation and greater leakage control. • Better understanding of sustainable yields and revision of allocation decisions. • Greater catchment manipulation for increasing water yield. • Greater water trading between industries and recycling.
Reduced reliability of water supply (private).	• Water harvesting. • Competition for water. • Deeper bores. • Improvements in water use efficiency and management. • Greater public and political awareness. • Re-use of waste water in industry.	• Full licensing and pay-for-use. • Greater water use efficiency and reduced water use. • Establishment of collectives/cooperatives for water. • Water industry restructure. • Infrastructure investment.
Reduced stream and estuary flow and water quality, reducing ecological and social values.	• Development of environmental water provisions, and reduced take-offs. • Increased riparian protection. • Fishing restrictions. • Salinity diversions. • Promotion of public awareness, especially of contaminants in run-off and drainage water.	• Vulnerability assessment of ecosystems. • Improve environmental water provisions: science, determinations and implementation. • Sediment dredging. • Greater land use controls. • Better storm water management and treatment.
Drying of groundwater reliant ecosystems and reduced water quality.	• Reduced use of superficial aquifer. • Localised mitigation through pumping. • Increased valuing of wetlands. • Augmentation of cave water supplies. • Ecological adaptation.	• Vulnerability assessment of ecosystems. • Improve environmental water provisions science, determinations and implementation. • Improved control of nutrients. • Better planned releases of water into ecosystems. • Improved drainage systems.
Reduced water availability for fire fighting.	• Deeper bores. • More and more timely strategic fire/fuel load management.	• Greater reliance on prescribed burning.

Key impacts	Key current responses	Key future responses
Water (continued)		
Challenged regulatory and management systems.	• Reassessment of water resource needs. • Recognition of stress in the regulatory system.	• Better coordination between industry and regulators. • Robust legislation. • Structural changes in water management in WA. • Increased regulatory skills base. • More community involvement. • Development of a 'water court'. • Establishment of water resource management committees.
Seasonally variable flooding.		• Risk assessment – based mitigation/adaptation.
Stranded/underperforming assets/infrastructure.		• Investigate alternate uses. • Implement water quality improvement programs.

Key impacts	Key current responses	Key future responses
Biodiversity		
Changed biodiversity and increased threats to natural assets.	• Artificial maintenance of cave fauna habitat. • Improved nature conservation planning at regional level.	• Scenarios, based on best available knowledge of critical thresholds for habitat requirements; dominant and keystone species resilience and vulnerability. • Palaeoclimatic research to provide context for understanding future climate change. • Test the assumption that temperature and rainfall are major determinants of geographical ranges of species. • Better understand 'knock-on' effects to less visible components of biodiversity. • Develop techniques for distinguishing climate from other disturbance factors. • Use fine scale meteorological calibration to support larger scale models.
Shift to more open plant community structures.	Fire management objectives set to achieve protection of denser vegetation types (e.g. Walpole Wilderness Area).	• Understand the extent of the shift particularly at the margins of changing rainfall zones and in heaths and wet forests. • Adopt more strategic use of remotely sensed data to monitor shifts.
Xeric shift resulting in extinctions.	Gondwanan project linking nature reserves and national parks in the Lower Great Southern.	• Expand the corridor system throughout highly fragmented landscapes (e.g. Wheatbelt, Swan Coastal Plain). • Select key indicator species for study (e.g. mesic species).

Key impacts	Key current responses	Key future responses
Biodiversity (continued)		
Compounded environmental stresses.	• CALM's Western Shield program is reducing predation by foxes on native fauna. • Tuart and wandoo Australian Research Council Linkage projects investigating the hierarchy of threatening processes involved with tree decline.	• Better understanding of the likelihood of extreme rainfall events in activating outbreaks of pests and diseases. • Investigate the interaction of fire regimes with other environmental stressors. • Consider the exacerbated impact of feral predation in a more arid climate.
Changed distribution of species.	Monitoring systems (e.g. Forestcheck and recovery plans).	• Improve the ecological condition of inner Wheatbelt road verges. • Improved database for existing records. • Extend monitoring to the entire of south-west WA.
Altered fire regimes and impact on biodiversity and natural assets.	Fire and biodiversity research (e.g. Walpole fire mosaic study has been commenced).	Investigate impact of drying climate on annual grasses, fire severity and understorey structure.
Reduced biodiversity on and off reserve systems.	Increased attention to conserving vegetation remnants on farmlands (e.g. CALM's Land for Wildlife project).	Commence effective strategic planning to build linkages that buffer climate-forced distributional changes.
Reduced protection and impeded recovery of threatened species.	Partnership with the Millennium Seed Bank Project.	Increase the level of storage of seed and captive breeding of native animals.
Changed plant and animal species condition such as tree decline.	Tuart and wandoo 'task forces' operating.	Ameliorate environmental stressors that are amenable to human management.
Changed water quality and impact on aquatic flora and fauna.	Coordinated planning of wetlands in regional parks.	• Commence captive breeding of aquatic flora and fauna ex situ and in situ. • Reduce the quantity of perennial vegetation where appropriate to increase inflow to wetlands and streams.
Changed productive capacity of forests.	Proposals to thin overstocked forests to increase water yield (e.g. Wungong Catchment).	• Intensive management (e.g. irrigate, fertilise) of designated stands to promote tree growth.
Changed eco-recreation and visitor services.	Improved management planning of newly created forest national parks.	• Minimise degradation of old growth stands by wildfire. • Engage more fully with the public on the impact of climate change on biodiversity. • Encourage volunteer involvement in adaptive management programs.
Changed heritage and cultural values.	Prescribed burning is protecting heritage and cultural assets.	• Minimise degradation of heritage and cultural assets by wildfire. • Develop better procedures for valuing intangible assets. • Initiate more extensive planting of trees of appropriate species.

Key impacts	Key current responses	Key future responses
Human issues		
Generic matters		**Response model** – A model of response types and needs that provides a framework for identifying information and communication needs and research and communication programs.
Extreme events and variability: • sea level rise • storm surge • coastal erosion • heat extremes • lightning • fires • flooding	• Limited coordinated response to changes in extreme events – weather reports, warnings. • Possible spontaneous responses, e.g. increased use and promotion of efficient air conditioning systems. • Fire and lightning response mostly confined to consideration by forest managers. • Limited apparent response to coastal erosion and damage, including heightened storm surge. • Reduced rainfall in parts of south-west may have reduced flooding and encouraged complacency regarding flood plain development.	**Research** – Improved knowledge of current and projected climate conditions and management of changing risks in extremes. **Information** – Clear, and locally- and sector- specific. • Community interaction to determine the type of information required and desired. • Link climate change with sustainability through an integrated response across government. **Communication** – Promote community understanding of possible impacts and responses. • Profile climate-related 'stories' from different community sectors. • Generate community discussion on climate change. • Identify effective communicators providers, e.g. WA Museum.
Impacts on physical infrastructure: • buildings • transport • water supply • energy • specific industries, e.g. tourism	Policy development in professional bodies. No coordinated in situ response other than in water supply. Insurance industry is beginning to respond.	• Planning policy towards more climatically sensitive design and planning. • Professional bodies should review and update codes of practice to reflect new climate knowledge. • Tourism industry policy should take account of new climate knowledge. • Government should determine and communicate how climate-related risk to public and private infrastructure is to be addressed.
Impacts on health: • heat stress • vector borne diseases – changes in transmission potential and range • water pollution • air pollution	Limited coordinated response; some through 1997 NGS and existing and evolving public health programs.	• Identify and work with population sectors most likely to be affected, e.g. aged and rural persons. • Integrated policy and education, including links between issues, and levels of government. • Understand potential disease transmission mechanisms e.g. for Ross River virus. • Understand potential changes to regional air circulation.
General social issues • equity	No coordinated response.	• Ensure the needs of most vulnerable sections of the population (e.g. aged, poor and Indigenous) are addressed.

Key impacts	Key current responses	Key future responses
Marine and coastal		
Increasing Sea Surface Temperatures (SSTs) and increased risks of bleaching of corals.	• Global scale (NOAA 'Hotspots') SST monitoring network for prediction of coral bleaching threat designed and operational. • State-wide (institutional) monitoring networks and frameworks partially designed and implemented. • Site specific (industry) strategic and compliance monitoring networks implemented. • Various related research projects underway through State and Commonwealth research institutions. • Climate change node in WAMSI (WA Marine Science Institution). • IOCI.	• Establish a climate change science research capability in Western Australia, providing improved scientific framework and capacity for assessment of current and future climate change related impacts. Also to provide relevant policy, planning and tools for resource managers to invoke adaptive management. • Establish a State-wide observation system to develop long term data at key reference sites on key bio-physical marine, meteorological and hydrological (including terrestrial) variables. • Use the data from the observing systems to characterise natural variability, detect ecosystem response and impacts and provide information for models and adaptive management. • Develop and validate predictive models, to facilitate predictions of impacts due to climate change, and therefore facilitate adaptive management. • Improve use of existing institutional frameworks to facilitate the above (across Government policy formulation and implementation, marine science, natural resource management, planning, safety, environmental protection, etc.).
Changes to chemical characteristics of sea and associated potential stress to marine communities, e.g. corals, (from acidification, for example).	• State-wide (institutional) monitoring networks and frameworks partially designed and implemented. • Various related research projects underway through State and Commonwealth research institutions. • Climate change node in WAMSI. • IOCI.	As per response to SSTs and increased risks of bleaching of corals.
Changes in abundance and distribution of fish and thus impacts on fisheries.	• Understanding the relationship between environmental variables and abundance and recruitment of fish.	Development of oceanographic models to predict changes in SSTs, currents, etc and assess likely impact of climate change on fish abundance and distribution.
Rising mean sea levels and potential geomorphologically related impacts to the coastal zone (e.g. erosion and accretion).	As per response to SSTs and increased risks of bleaching of corals.	As per response to SSTs and increased risks of bleaching of corals.

Key impacts	Key current responses	Key future responses
Marine and coastal (continued)		
Changes to meteorological regimes, and associated changes to the nature and frequency of the energetics of oceanographic processes (e.g. waves, winds (mean and extreme events), currents) and associated changes to the nature and (i) intensity of energetic processes and concomitant physical risk to marine and coastal ecosystems (ii) and potential geomorphologically related impacts to the coastal zone (e.g. erosion and accretion).	As per response to SSTs and increased risks of bleaching of corals.	As per response to SSTs and increased risks of bleaching of corals.
Changes to hydrodynamic regimes (e.g. regional and local scale currents, waves, currents) and associated changes to the ecology of marine and coastal ecosystems.	As per response to SSTs and increased risks of bleaching of corals.	As per response to SSTs and increased risks of bleaching of corals.
Changes to terrestrial hydrologic regimes and associated changes to the nature (e.g. sediment loading, nutrient content) and frequency/intensity of coastal discharges to marine and coastal ecosystems.	As per response to SSTs and increased risks of bleaching of corals.	As per response to SSTs and increased risks of bleaching of corals.

Key impacts	Key current responses	Key future responses
Commerce and industry		
Reduced water availability.	• Water use restrictions. • Development of new sources, e.g. sea water desalination. • Switching to private supply sources. • Industry water use efficiencies publicised. • Competition for water allocation. • Improvements in water use efficiency and management. • Re-use of waste water in industry – Kwinana Water Reclamation Plant.	• Develop open water market, water trading, and private industry supply. • Water industry restructure. • Revision of sustainable yields placing increased pressure on allocation decisions • More water re-use and recycling. • Greater water trading between industries and recycling. • Improved water use efficiency in industrial processes. • Full licensing and pay for use. • Increased use of alternative sources. • Water industry competition and restructure.
Changing sea levels.	• Build small increase into new marine infrastructure.	• Revision of standards for structures etc. • Increased allowance for storm surge etc in new structures and increased protection for existing coastal structures.
Increased intensity of extreme events.	• Compliance with existing standards. • Increasing insurance premiums.	• Revision of standards for structures etc. • Increased insurance premiums or increased use of self-insurance.

Cleaner production and eco-efficiency.	• Technology improvements.	• New technology development is the key to reducing the greenhouse gas (GHG) intensity of operations and achieving cost effective large-scale emissions abatement.
		• Most important in largest industries:
		  • zero emissions coal fired power generation;
		  • enhanced iron making technologies;
		  • development of advanced aluminium smelting cells; and
		  • production and storage of hydrogen.
		• Product stewardship.

CO_2 emissions and future regulation.	• Greenhouse Challenge (Plus) Australian Greenhouse Office.
	• Mandated Energy Efficiency Opportunities (Commonwealth DITR).
	• Reducing CO_2 emissions through technology improvements (voluntary actions outside of above two).
		• Greater pressure to minimise CO_2 emissions and move to mandated systems.
		• Industry support for policies that address climate change – both domestically and internationally – that are effective, comprehensive including major emitters, equitable, and internationally consistent.
		• Market-based instruments, including emissions trading, can yield timely, effective and sustainable emissions reduction.
		• Agreement and rules for and accounting of emission trading.
		• Emissions trading for industry supported by industry where:
		  • no impact on competitiveness;
		  • flexible and efficient;
		  • long term certainty;
		  • universality;
		  • includes major emitters; and
		  • does not discriminate against early movers.
		• Economy wide, no discrimination between sectors or fuels.
		• Encourages sequestration.

2. Research requirements

Climate science needed to manage informed adaptation within and between sectors

One of the specific objectives from the IOCI Workshop was to provide sector input into the climate science needed to support Government, industry and community decisions and to use this information to define the IOCI's future focus and directions.

The following analysis of the workshop responses on sector needs has been structured to guide the planning of a future IOCI initiative. Individual sector responses expressed in dot point form are given in Appendix A.

What are the most important sectoral climate science needs?

It is important to align IOCI research with sector and community needs to achieve informed adaptive responses. Sectoral responses for climate science requirements broadly fell into the following themes:

- good data sets from meteorological observations and associated output from climate models;
- science to provide information for tactical decision making (seasonal to five years);
- science to provide information for strategic decision making (five to 20 years);
- science to inform policy decisions making; and
- communication strategies and initiatives.

Good data sets from weather observations and climate models

All sectors raised the importance of high-quality observational data sets, available data sets from model simulations and the development of impact models that could use relevant climate data sets. Climate observation data sets need to be spatially rich, and downscaled future climate data sets need to be credible. Specific examples of data requirements included:

- high quality climate records;
- more data on extreme events, including wind and lightning;
- palaeo-climate data sets and palaeo-climate model simulations;
- State-wide marine climate observation systems to acquire baseline data to monitor reef impact, ocean energetics, current changes, coastal changes and impact of ocean state changes on the climate; and
- past and projected climate data sets suitable for use in BIOCLIM and other biophysical models.

Climate science to inform tactical decisions

Climate science is required to support key decisions, and draw on factors such as:

- seasonal and intra-seasonal prediction of rainfall and soil moisture for agriculture;
- regionally-specific seasonal predictions of extreme events for fire management; and
- climate trends for fire management.

Climate science to inform strategic decisions

Climate science needs to provide credible future rainfall projections for south-west Western Australia, particularly:

- future (and worst case) change (and rate of change) in rainfall expressed as probabilities of change;
- seasonal rainfall variability (and change in variability); and
- seasonality and spatial variability of rainfall change and variability.

Climate science to inform policy decisions

All sectors supported the thesis that informed decision making on adaptation requires that policy is built on good science and sound knowledge and that adaptation to climate change should be linked to sustainability. This sentiment corresponded with the statement by Wally Cox in the Living with our Climate seminar (15 August 2005) that "Western Australia must plan to adapt to inevitable climate change and it is imperative we enhance our understanding of the impacts of climate change in Western Australia".

Several sector-specific climate science needs were identified:

- Water – climate projections having sufficient skill to support future yield allocations based on resources rather than volumes.

- Biodiversity – climate parameters at scales relevant to climate impacts on biodiversity
- Marine – climate science to manage marine gains and losses due to climate change. (WAMSI and IOCI bring complementary skills to this challenge.)
- Infrastructure and planning – impact of climate change on planning decisions and infrastructure codes. Policy needs to be based on both climate change and change in population demographics and therefore integrated studies are needed.

Communication strategies and initiatives

Effective communication of climate science outcomes was recognised as an essential part of IOCI.

IOCI was seen to have an important role in supporting the responsibilities of sectors to communicate and apply core science to support their decision making.

What are the key science needs of the sectors?

The sector-specific science requirements could be broadly classified into the integration of climate science into (a) biophysical science frameworks and (b) socio-economic science frameworks.

Bio-physical climate frameworks

- Water sector
  - integrate climate and catchment/aquifer/ land use information to model sustainable water yields (and quality) and predict water volumes less than a year ahead for operational planning; and
  - improved monitoring and understanding of interactions between ground and surface water and better understanding the palaeo-climate record.
- Biodiversity
  - broad-scale assessment of impacts of climate change on biodiversity, requiring fundamental research that includes application of palaeo-climate tools;
  - assemble, apply and review biodiversity baselines with climate data; and
  - develop and apply bio-climate models.
- Agriculture and forestry
  - science that extends to the adaptability of existing crops;
  - prediction capability on impacts of pests and diseases; and
  - hydrological impacts, including salinity and effects on farm water supplies.
- Marine
  - improved coastal topography and sediment dynamics; and
  - understanding of palaeo-memory in past sea levels.

Socio-economic science frameworks

- research to develop technologies to build resilience into production systems;
- tools to improve a seasonal management capacity for agriculture;
- economic modelling to estimate the risks and returns from climate change for different sectors;
- monitoring of climate trends to assist with production systems risk management;
- assessment of costs – including social equity implications of adapting and not adapting;
- social science studies to determine attitudes and social barriers that will determine or influence responses to the climate change;
- health impacts of climate change; and
- where climate change impacts on a sector it impacts on the business in that sector.

3. Governance issues

What environment is required to foster informed adaptation?

Three factors are necessary for successful use of information for adaptation: an informed policy culture in Government, recognition by Government departments that climate is an important issue and strong public awareness of climate issues. The workshop participants identified several practical manifestations of these factors.

Policy environment

- A Government natural resource management policy (including water) that includes climate change and climate variability.
- Economic policies that reflect the importance of climate change and biodiversity.
- Policy support to retain the climate science focus of IOCI on WA.

Institutional responses

- Institutions develop more sophisticated methodologies for decision making under uncertainty and alternate governance models.
- Support to develop and implement biodiversity protection systems in the face of climate change.
- Develop departmental cultures where marine and climate change science is acknowledged, reviewed and applied.

Public engagement

- Research to ascertain acceptable levels of impact of climate change.
- Informed community engagement as part of the decision-making process for resource management.
- IOCI website links to facilitate professional and public access to climate variability and change information.

Sectoral interactions

Each group was asked to identify its importance to the other workshop discussion groups. The following table summarises the responses on a scale of zero to three ticks. The vertical column is the sector's rating on the importance of other sectors on it.

	Water	Agriculture and forestry	Biodiversity	Human issues	Marine and coastal	Commerce and industry
Water		✓✓✓	✓	✓✓		✓✓
Agriculture and forestry	✓✓✓		✓✓	✓✓		✓✓
Biodiversity	✓✓✓	✓✓		✓✓	✓✓	✓
Human issues	✓✓✓	✓✓	✓✓✓		✓✓✓	✓✓
Marine and coastal	✓✓		✓✓✓	✓✓✓		✓✓
Commerce and industry	✓✓✓	✓	✓✓	✓✓	✓✓✓	

The significance of these responses is that there are differences of perceived importance between sectors. For example, water perceived biodiversity as only mildly relevant and significant to its resilience to climate change (one tick) whereas water was perceived to be a very important factor for the resilience of biodiversity to climate change (three ticks). The strongest cross sector engagement and cooperation on climate change adaptation initiatives will occur where both groups see strong mutual benefit.

Potential links and collaborations for IOCI

IOCI's governance model should be designed to facilitate links and collaborations with relevant entities. IOCI could play a more effective leadership role in maximising the benefit to the state of climate science knowledge and understanding through:

- amalgamating climate-related activities within Government, science agencies and universities;
- extending to the economically important and potentially vulnerable northern parts of WA, especially relating to extreme events;
- stronger planning linkages with CSIRO climate related programs such as 'Water for a Healthy Country', 'Wealth from Oceans' and WAMSI;
- better and more widely engaging with Government agencies;
- collaborating with similar science partner studies in eastern Australia (e.g. SEACP);
- engaging Commonwealth agencies (CSIRO, AGO, BoM, Cooperative Research Centre for Greenhouse Accounting);
- increasing awareness of international initiatives that will benefit WA (e.g. tsunami warning system initiative); and
- collaborating with industry operators and organisations to exchange research and policy knowledge and developments.

What organisational improvements can be made to IOCI?

Finally, the workshop addressed where organisation changes would lead to a more effective IOCI. The discussion groups identified and recommended the following changes to the current governance and funding model for IOCI:

- developing dedicated science partner leadership position in WA;
- replacing the current distributive funding model with single line core funding;
- funding increased for communications and sectoral engagement activities;
- extending IOCI to other jurisdictions while maintaining independence;
- representing industry on the IOCI panel; and
- maintaining independence of IOCI.

Appendix A: Sector reports to the IOCI Workshop

Agriculture and forestry

Most important sectoral climate science requirements:

- further focus on existing IOCI program current climate, changes, drivers, variability, how it relates to past climates, variability in a spatial and temporal context;
- information about plausible future climates, including where this sector is likely to be headed in terms of future risk; and
- observation systems in productive regions to provide information about climate trends to enable information about climate about production.

Need to manage seasonal variability as a shorter term and recurrent issue – seasonal prediction.

- Aspirational outcome: regionally-specific seasonal prediction of climate, including extreme events.
- Realistic in short term: better use of existing information and better communication to user groups.

Future climate aspects are important for planning of future industry development and risk assessment.

Key non-climate (sectoral) needs:

- bioclimatic modelling capability on pests and diseases as well as crops;
- generic capacity to understand current and project future resilience and robustness of landscape to deal with seasonal variability and climate change;
- knowledge of hydrological impacts and water supplies on other sectors;
- knowledge of how climate change might impact on international commodity markets and prices;
- impact of declining terms of trade on the capacity of the agricultural sector to respond to the impacts of climate change; and
- extend climate adaptability and flexibility of existing crops.

Other sectors important for this sector to be able to respond effectively in the following areas:

- skill sector – biological and geophysical research community (very important);
- finance sector – agribusiness and finance;
- Government sector – environmental regulations and management systems;
- lack of people in rural areas to provide essential services, such as volunteer fire fighting, which may generate an increasing reliance on services supplied by Government;
- education – improve skills of future farmers especially in their capacity for climate management; and
- public health – maintain/improve rural health, support services during dry years to cope with an increased incidence of depression.

Geographic scope and collaboration:

- mining and manufacturing industry – especially with the offshore oil/gas industry to gather information about tropical cyclone generation and intensity;
- health – if south-west WA is a 'climate canary' then information in how the region has responded to extended climate change and how health statistics have changed during this period may help inform other regions and sectors about potential impacts;
- insurance – extreme events analysis; and
- finance – there are opportunities for carbon sequestration.

Scope – no consensus:

- There is good reason for current IOCI geographic scope, and there appear to be trade offs for the IOCI's capacity to serve this region if the rest of State is included. However, it is necessary to ensure that extensions would not reduce IOCI's capacity to deliver useful outcomes.
- The Kimberley is important but has different climate issues than south-west Western Australia.

Water

Most important climate science needs for the sector:

- understand the dynamics of climate change and variability better, including rainfall for south-west WA, to provide data for policy and planning;
- develop of probabilities around climate scenario estimates;
- distinguish between climate change and climate variability;
- differentiate effects on summer and winter rainfall;
- break down spatial trends between north to south and east and west, and even within the south-west; and
- understand meteorological shifts that have or will occur.

What can be done in the sector now?

- incorporate climate science into water quantity and quality analysis and projection;
- decision-makers need to quantify the water resources that will be available on a volumetric basis and get community agreement on how this is to be shared and acceptable impacts;
- more sophisticated decision making under uncertainty – e.g. shorter term water abstraction licences may be considered, recognising that investment seeks certainty; and
- quantified resources shared, rather than adopting a volumetric approach to water allocation.

Most important issues for other sectors?

- Forestry and agriculture, especially ‘burning and thinning’ to help water resource quantity and quality management.
- Ongoing review of governance in water sector.
- Land use planning to protect water resources.

Collaborations:

- with rest of southern Australia interesting but only emerging;
- with marine sector;
- each agency should have an active climate coordinator in the agency business plan; and
- IOCI needs a full-time science leader.

Biodiversity

Major science issues:

- What relevant and accessible biodiversity databases exist?
- What evidence exists about changes to ecosystems? What links exist?
- A conceptual model capacity of the biodiversity of south-west Western Australia needs to be developed.
- Climate needs to be integrated into in existing biospheric models.
- Climate science needs to be integrated in management through an adaptive management approach.
- Ecosystem service values needs to be integrated into economic assessments.

Major climate science themes

1. Broad-scale review of science about biodiversity:
    - ‘keystone’ or indicator species, which are particularly sensitive to climate change need to be identified;
    - threshold limits, or stepwise changes beyond which a cascade of ecosystem impacts would result, needs to be identified;
    - palaeo-information must be gathered and examined, especially during the past 1000 years to gain an indication of how ecosystems might respond to future climate conditions;
        - Is there national coordination and encouragement of palaeo-climate science?
    - good projects now addressing biodiversity and climate change impacts must be learned from.

2. Existing Australian environmental databases, especially biodiversity – climate change data:
    - What is the quality of the databases (e.g. Forestcheck) of sectoral and other data relevant to managing biodiversity/landscape climate change impacts? Forestcheck the comprehensive database system, which is a model systems that need to be developed for all ecosystems
    - Need to data mine at differing levels: community to all levels of Government and universities.
    - Need to develop new databases in line with frameworks and guidelines.
    - Establish documentation for databases that clearly identifies IP issues.
3. Develop models to analyse and project biodiversity and ecosystem impacts of climate change:
    - clarify thoughts, identify and validate relationships, prioritise research requirements;
    - ascertain whether there are any models available overseas that could be adapted for WA circumstances;
    - determine whether models should be accessible to community members as well as scientists; and
    - a workshop can be a good mechanism to stimulate model development.
4. Applied adaptive management approach:
    - Trials of adaptive responses by CALM, large land holders and other land managers to explore options for climate change adaptation to buffer the resilience of ecological systems, e.g. potential of corridors for genetic migration.
    - Genetic threats: loss of genetic diversity; genetic weeds.
    - Terrestrial climate monitoring stations.
5. Ecosystem services values:
    - Put signals of the importance of ecosystems services into economic assessments

Collaborations:

- Between all types of landowners, e.g. CALM, farmers and pastoralists, NRM groups etc.
- Learn from other jurisdictions how they implement the Convention on Biological Diversity to address biodiversity protection under climate change.
- There is a plan to prepare an economic map of WA, it would be good to put biodiversity values on the map.

Human issues

What is required for the sector to respond effectively to climate change?

- Locally specific information identified through local community interaction.
- Government to provide a framework for passing on climate information, bringing together the activities of the agencies currently providing information about climate change.
- Link climate change with sustainability.
- Barriers to adoption include how the science is marketed, independence of the institutions providing the science and the confidence people have in the science.

Most pressing climate information needs:

- observations of lightning and wind events;
- adequate information about extremes; and
- regionalised climate change information for the whole of WA.

Most pressing sectoral science needs:

- costs of adapting and not adapting;
- understanding of the distribution of costs and benefits (social equity) and how that is going to be addressed;
- capacity of the sector to respond to the knowledge within sector;
- interdisciplinary issues: social sciences, including attitudes to change and barriers to change in response to climate change;
- impact of climate change on health; and
- population pressures as a contributor to climate change.

Importance to other sectors:

- all climate-sensitive sectors are relevant;
- important sectors are those where there is a flow of impacts to or from this sector; and
- there is a need to determine what society is willing to accept and willing to pay to avoid in terms of the scale and nature of adverse impacts.

Conflict:

- social dislocation through a loss of sense of place as environment changes.

Collaboration:

- involvement of key sectors such as health, planning and infrastructure in IOCI;
- extend IOCI into other parts of WA, involve other jurisdictions, maintain independence of IOCI, involve Indigenous people in south-west WA, WA Museum and local universities might be helpful;
- maintain IOCI as an independent provider of scientific information;
- need to ensure local authorities can access good information in discharging their responsibilities;
- new regulations under the Health Act could help embed climate change and other global processes into sustainability; and
- climate change supports an approach to management on a bioregional basis, rather than existing jurisdictions.

Marine

What does the marine sector need in terms of management and planning?

- Information to inform policy making and institutionally based implementation.
- An integrated state-wide observation system to generate good information about key fundamental processes and changes as they occur.
- Greater effort in developing predictive models to enable effective utilisation of information that is both currently available and that will be gathered in the future, e.g. impact of increased acidification from increasing SSTs on corals and impacts of increased oceanic energetics on ocean currents.
- To take advantage of existing institutional frameworks to provide a home for the proposed improved monitoring systems – e.g. Department of Fisheries for monitoring fisheries populations and CALM for monitoring of marine protected areas about system conditions and processes in undisturbed marine areas.

Non-climate needs:

- coastal topography – especially important for flooding on low-lying coastlines;
- sediment dynamics;
- to build a constituency that understands the need for adaptation responses to climate change adaptation action through education and communication through existing mechanisms where possible (e.g. Department of Education curricula and existing Government consultation programs);
- an economic analysis of adaptation;
- more sophisticated understanding of the palaeo-memory inherent in past sea levels;
- to ensure that existing information relevant to marine studies and climate change is acknowledged and reviewed and used;
  - Existing ocean-atmospheric model results and outputs from the US Reanalysis Program: Climatology for the New Millennium would be useful for current WA management.
  - There is much better information now about coastal dynamics than was available 10 years ago.
- ensure that any initiatives from this effort or others adequately review existing information and knowledge; and
- analyse local Government use of science for coastal management.

Collaborative links:

- There are good opportunities for collaboration between IOCI and WAMSI, whether the two entities merge or collaborate as independent entities.
- Embrace national and international marine initiatives.
- Palaeo-climate.
- Australian Institute of Engineers
- Tsunami warning system initiative.
- Link with the Department of Education.
- Existing institutional NRM frameworks.

Industry and commerce

Industry needs:

- clear standards, good predictions of climate change impacts, transparent application process, quick approvals to achieve certainty and timeliness;
  - Industry operates under its own industry standards as well as Government regulations and community expectations.
- some industry operators and groups have extensive internal expertise on climate change, but many small industry operators have little or no knowledge or capacity in climate science and so must rely on industry bodies.

Climate change science requirements:

- accurate information and advice about nature and direction of climate trends;
- climate change impact assessments for the whole of the State, given the economic importance of the Pilbara and other regions; and
- policy built on good science and knowledge, not on ‘perverse’ interpretations of IPCC and other reports.

Other sectors important to the industry and commerce sector:

- Virtually every other sector, including health, agriculture, fishing, water supply, environmental management, urban development and so on is important to WA industry and commerce services. Impacts of climate change on those sectors will impact on business activities in WA.
- Planning for accommodation needs to take account of the impact of climate on the health and safety of the workforce.

Collaborations:

- Support any inter-state collaboration that does not diminish the IOCI focus on WA.
- There would be value in industry having some representation on the IOCI panel and receiving briefings from climate change scientists.

Communications:

- Oral history of climate change – e.g. radio interviews.
- NERC research – major program in 2003/04 on climate change scenarios – translation of climate modelling scenarios into land cover being lost, loss of species and ecosystems, agricultural changes.
- Role of the internet and IOCI website, with links to other websites, to facilitate professional and public access to information.

Appendix B: Workshop participants

John McGrath (Agriculture and Forestry)	Forest Products Commission
Ross Kingwell	DAWA
Ian Foster	DAWA
Ian Smith	CSIRO
Carina Moeller	CSIRO
Tom Lyons	Murdoch University
David Jones	Bureau of Meteorology, National Climate Centre
John Cramb	Bureau of Meteorology, WA Regional Office
Jo Molin	DAWA
Jo Mummery	Australian Greenhouse Office
Gary English	Farmer
Don McFarlane (Water)	CSIRO
Ed Hauck	Department of Environment
Graeme Hughes	Water Corporation
Miles Dracup	Water Corporation
Simon Rogers	Department of Environment
Phil Commander	Department of Environment
Roger Jones	CSIRO
Scott Power	Bureau of Meteorology, Research Centre
Steve Charles	CSIRO
Rae Moran	Victorian Government
Ray Stone	Department of Environment
Drew Haswell (Biodiversity)	CALM
Ian Abbott	CALM
Pauline Treble	Australian National University
Paul Barber	Murdoch University
Linda Chambers	Bureau of Meteorology, Research Centre
Barry Wilson	CALM
Rick Sneeujagt	CALM
Christine Sharp	Conservation Council
Tom Rose	Department of Environment
Richard McKellar	CALM
Simon Dawkins (Human)	Climate change and sustainability consultant
Brian Sadler	IOCI Chair
Ann Bennett	Department of the Premier and Cabinet
Craig Hynes	Fire and Emergency Services Authority
Sue Graham-Taylor	WA Museum
Jan Starr	NRMC
Pandora Hope	Buntine Marchagee Recovery Catchment
Terry Maher	CALM
Nick D'Adamo (Coastal and Marine)	Department of the Premier and Cabinet
Rosh Ireland	Department of the Premier and Cabinet
Nick Caputi	WA Fisheries
Mervyn Lynch	Curtin University
John Church	CSIRO
Ming Feng	CSIRO
Robert Kay	Coastal Management Consultant
Robert Tregonning	Department of Fisheries
Sue Hill	Environmental interest
Ian Briggs (Industry and Commerce)	DOIR
Ray Wills	CCI
Peter Knight	ATSE
Anoushka Walster	DOIR
Neville Nicholls	Bureau of Meteorology, Research Centre
Shona Zulsdorf	Council of Minerals and Energy
Colin Murray	Environmental Protection Authority
Bryson Bates	CSIRO
Brian Ryan	CSIRO