7

Filling the Gaps

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Significant knowledge gaps continue to exist. These gaps mean that the net cost or benefit of unmitigated climate change in Australia is highly uncertain (section 6.1) and cannot be compared objectively with the cost of mitigation. Moreover, knowledge of impacts on particular systems in particular locations is very imprecise, as is the understanding of adaptation strategies to minimise harm and maximise any benefits. Without this knowledge base, policymaking regarding adaptation and mitigation cannot be soundly based on economic considerations and may not be effective in avoiding significant damages to the economy, ecology and people. Research priorities that might help to remedy this situation follow.

The IPCC TAR Synthesis Report (Watson and the Core Writing Team, 2002) presented a list of key uncertainties in answer to the final question the authors were asked by decision-makers. The list focussed on climate change and attribution, future emissions of greenhouse gases and aerosols based on the SRES and stabilisation range of socioeconomic scenarios, and future changes in global and regional climate. They also addressed uncertainties regarding regional and global impacts of changes in average climate and climatic extremes, and lastly, on the costs and benefits of mitigation and adaptation. The Synthesis Report can be viewed on the IPCC website at: <http://www.grida.no/climate/ipcc_tar/>

While all the gaps identified by the IPCC are important, here we will focus more on those that are of particular relevance to Australia.

7.1 Indicators of Climate Impacts

Although long-term monitoring programs are in place for physical indicators (such as climate variables and sea level), work is still desirable on designing and implementing long-term monitoring programs that cover vulnerable animals, plants and ecosystems, and systematically examine them for the effects of climate changes. Flora and fauna with presently restricted or marginal climatic ranges would be most appropriate (sections 2.2.2 and 4.2.8). (Candidate indicators for the UK are presented in Cannell *et al.*, 1999.) This need was discussed at a workshop organised by the Biological Diversity Advisory Committee where potential indicators of plant and animal physiological responses to climate and atmospheric carbon dioxide concentrations, changes in phenology and in distribution and abundance were identified (Howden *et al.*, 2003b). Recommendations for further action were adopted. See the BDAC website at: <http://www.ea.gov.au/biodiversity/science/bdac/>

7.2 Underpinning Physical Knowledge and Improved Scenarios

Improved impact assessments will depend on better understanding of how climate change may influence factors such as the frequency and intensity of El Niños and related droughts, the intensity and location-specific frequency of tropical cyclones, and return periods for heavy rainfalls, floods, high winds, and hail. A special

need in Australia is to understand how these climatic changes will impact on fire frequency, spread and intensity, and on dust storms and water erosion that threaten the sustainability of our forests, agricultural land and also the riverine and coastal coral reef ecosystems.

Oceanic issues include understanding the mechanism and possible impacts on Australia of a slow-down or cessation of bottom-water formation (section 2.1.4), predicting the impact of warming of the oceans on the Antarctic ice shelves and determining the influence of greenhouse warming on currents, upwelling, and nutrient supply. More knowledge is needed about influences of greenhouse gas related cooling in the stratosphere on ozone depletion, regional UV radiation levels (section 4.5.7), and its possible impact on surface climate (section 2.2.1). Explanations are needed for observed sudden shifts in rainfall and other climate patterns (section 2.1.4) including the observed change in the south-west of Western Australia in the 1970s. All of this knowledge is needed to improve scenarios of regional climate (including ocean behaviour).

A better understanding of natural climatic and oceanic variability is needed, as these combine with climatic change to determine impacts.

7.3 Underpinning Biological Knowledge

The sensitivities of many Australian plant and animal species and ecosystems to climate changes, as well as the potential threats to biodiversity, are still unknown (section 4.2). Knowledge is required for assessment of potential impacts and for development of conservation strategies. This is important for marine and coastal environments, including coastal freshwater wetlands (section 4.2.7), as well as for terrestrial systems. Identification of relevant climatic thresholds for biological (and other) systems is needed (sections 2.1.4, 5.4 and 5.6). The effects of the time-varying balance between the beneficial physiological effects of increasing carbon dioxide concentrations and climate change on natural (indigenous) and managed ecosystems (section 4.3.3) needs to be better understood, especially in light of recent regional scenarios.

The role and climatic preferences of pests, parasites and pathogens (section 4.3.7) in Australia is particularly important, but needs far more work, despite a good basis in models. This applies particularly to knowledge of over-wintering success, interactions between species, modelling adaptations and their costs and benefits.

The role of fire, and soil erosion via dust storms and heavy rains, will almost certainly change with climate change in Australia (section 4.2.9), but the role of these phenomena in sustainable ecological and socioeconomic systems in Australia has not been adequately explored.

The IPCC Technical Paper on climate change and biodiversity (Gitay *et al.*, 2002) lists several information gaps, but they are in very general terms. They can be viewed on the IPCC website as above.

7.4 Underpinning Social Knowledge

Better knowledge is required about the vulnerability of particular population groups (including indigenous people), about how people and organisations have adapted to past climate variability and change, and about individual attitudes to adaptation and mitigation options. Work is needed to understand how different socioeconomic futures (demography, economic capacity, and technological change) (section 1.4.4) would affect vulnerability (sections 6.4.2 and 6.7) and on socioeconomic thresholds for change, such as economic non-viability and unacceptable risk.

7.5 Fisheries

There is insufficient information to enable confident predictions of changes in fisheries' productivity from climate change (section 4.3.5). This requires better knowledge of physical and biological processes in the ocean (as above) and improved information on the climate sensitivities of many species. Effects on estuarine fish-farming may be particularly important.

7.6 Health

Continuing work is needed on the potential for introduction and spread of significant disease vectors, including their sensitivity to climate, population shifts, and effectiveness of health services and biosecurity procedures (sections 4.3.7 and 4.5.9). Other health issues should be addressed, including potential effects of threats to water supply on remote communities (section 4.5.8), heat stress and adaptation to heat (section 4.5.2), and food and water-borne disease (section 4.5.6).

7.7 Regional Effects and Integration

Better quantitative sectoral knowledge is required about, for example, influences of climate change on water supply and demand (section 4.1.2), salinisation (section 4.1.4), and some crops and farming practices (sections 4.3.3 and 4.3.4). Because various sectors (e.g., agriculture, ecosystems, infrastructure, and hydrology) interact at the regional and national levels, continued work is needed on integrated assessment approaches and models that synthesise sectoral knowledge and draw on the social sciences (section 5.4), in rural and urban settings. Such models should include the impacts of other stresses, and of socioeconomic changes (section 1.4.4). Models of the physical economy that track fluxes and pools of materials, energy, land and water are required for national analyses.

Uncertainties need to be identified and dealt with in a risk assessment framework, where the probabilities of exceeding critical physical, biological or socioeconomic thresholds are quantified so that cost-benefit or other approaches can be applied to decision-making (sections 3.3 and 5.4).

7.8 Global Interactions

More understanding is needed of the interaction of global climate change impacts, and of mitigation policies, on Australian markets, sectoral change, and land use (sections 4.3.9 and 5.10). Another potential issue that has hardly been touched upon in Australian studies is the implications for Australia of increasing international inequity resulting from climate change impacts (see references in sections 2.1.4, 3.4, 4.5.8 and 5.10 and the discussion in Chapter 18 of McCarthy *et al.*, 2001).

7.9 Adaptation

Further objective studies are required, in close collaboration with stakeholders, on adaptation options and their acceptability, costs, co-benefits, side effects, and limits (chapter 5). Adaptation should be regarded as a means to maximise gains and minimise losses, with a greater exploration of opportunities (see section 5.3). Integrated studies are needed that cross sectoral boundaries, involve stakeholders, consider other stresses on communities and systems, and examine costs and benefits realistically. Adaptation to climate change and variability needs to be considered in the context of routine planning and decision-making as a necessary factor alongside other environmental and socioeconomic issues.

7.10 Costing

More comprehensive and realistic costings are needed for impacts and adaptation options, taking account of human behaviour and using up-to-date scenarios (section 6.1). Co-benefits

and side effects need to be accounted for (chapter 5), as does the issue of discount rates and their uncertainty in considering delayed effects and inter-generational equity (sections 3.2 and 3.3).

7.11 Communication of Policy-Relevant Results

If climate change issues are to be addressed by decision-makers, there will need to be better communication of results from research. This will come partly from consultation with decision-makers and other stakeholders to ensure that the right policy-relevant questions are addressed (section 5.4) and partly from effective communication of what is known, as well as the uncertainties. A risk-assessment approach geared to particular stakeholders seems likely to be most effective (section 6.6).