APPENDICES

APPENDIX 1. DESCRIPTION OF CLIMATE IMPACTS ON ENVIRONMENTAL CHANGE, CHANGES TO THREATS, AND BIODIVERSITY RESPONSES

The information presented here was used in assessing the implications of climate change on biodiversity in each of the ten agro-climatic zones of Hobbs & McIntyre (2005). The assessments are summaries in Section 5 and additional information is provided in Appendix 2. Some of the information presented here repeats that presented in Part A, Section 3 on the impacts of climate change on biodiversity. This Appendix was designed to accompany the impact assessments and stand alone from Part A.

The assessments focuses largely on ecosystem-level impacts, derived mainly from qualitative assessments of the impacts of possible changes to productivity, growing season and disturbance regimes. Assessments of vulnerability could be made with the information provided based on the relative magnitude and number of significant types of impacts that might face ecosystems in a zone. Many impacts that depend on the unique characteristics of species in each region, e.g. species with narrow distributions, have not been considered at this stage.

Temperature

Australia will get hotter; in all regions maximum and minimum temperatures in all seasons are expected to increase. The temperature is anticipated to increase 0.2 to 2.2°C by 2030, and 0.4 to 6.7°C by 2070. Spring and summer temperatures will increase more than autumn and winter; the warming will be up to 2 degrees greater inland than on the coast; and night-time temperatures will increase more than day-time temperatures. For temperate cities the average number of days above 35°C increases 4-18 days by 2030, and 9-56 days by 2070. The hotter temperatures will lead to less snow cover and a shorter snow season; fewer frosts; and a longer growing season in southern Australia (extend spring, summer autumn). The seasonality of moisture availability will be important mediator in determining the impact of increased temperatures on plants and animals. Summer growth may be reduced through increased moisture- and heat-stress, and winter growth may be increased by warming if water is available.

Rainfall

Rainfall is much harder to predict than temperature and the ranges on the predictions are much wider. In general, Australia will very likely be drier, but there will be regional and seasonal variations. South-western WA, southern SA and most of Victoria are very likely to be drier, while Tasmania, northern NSW, parts of southern Queensland and parts of NT may be slightly wetter (mainly in summer and autumn). The seasonality of rainfall will change, affecting the seasonality of moisture (also related to increased temperatures). Reduced winter rainfall may be critical for annual growth in southern states. Increased summer and autumn rainfall in parts of northern Australia may strengthen the seasonality of water availability. Rainfall is expected to be more variable and fall in more intense events, increasing runoff, rather than infiltration, and erosion; the season of rainfall may also affect runoff. There will be an increase in potential evaporation by up to 8% per degree of global warming across most of Australia, which is also very likely to significantly reduce flow rates of many river systems.

CO_2 concentrations

Globally, CO_2 has increased from 280 parts per million (ppm) to around 400 ppm. It is predicted that CO_2 will increase to between 540 and 970 ppm by 2100. In general (globally), this will lead (at least initially) to increased plant growth, increased water use efficiency, changes in C: N ratios, and changes in concentration and composition of defensive compounds and energy content in leaves; it will also lead to changes in growth form and structure of vegetation, and the mix of C_3/C_4 plants. However, the nature of the changes observed in lab and field experiments vary markedly between species and are highly dependent on water and nutrient availability (under nutrient stress the advantages of increased CO_2 are greatly diminished). For some species the growth effects also appear to be much less in older plants than younger ones, possibly due to an acceleration of growth rather than an increase in lifetime growth. The effect also diminishes with higher CO_2 concentrations. For many species the net impact of climate change on seasonal growth will depend on a complex balance between increasing temperature, changing water availability and increased water use efficiency. Changes in rates of nutrient cycling in the soil will also affect CO_2 impacts.

Storms

An increasing proportion of rain is expected to fall in more intense events, and large storms and cyclones are expected to be more severe, with higher winds, causing more damage, flooding and coastal inundation. Cyclones may also move further south.

Sea level

Sea levels will increase which will lead to coastal inundation and affect mangroves, salt marshes and coastal freshwater wetlands. Freshwater aquifers may also be affected by saltwater intrusion, especially if recharge is reduced or societal extraction is increased.

Fire regimes: intensity, frequency, seasonality, extent

There will be a significant increase in high fire-risk weather in many areas, primarily through decreased relative humidity, but changes in temperature, wind speed and rainfall will also contribute. Also important is the increase in number of days > 30°C and possible increases in storms (lightening). Increased CO_2, and increased temperature and/or rainfall in some regions, will lead to increased plant growth and fuel load. Litter curing conditions and changed (reduced) wood and litter nitrogen concentrations reducing decomposition rates will also be important factors. In many regions this will lead to increases in the frequency and severity of fires and possibly changes in the seasonality of fire. Therefore, major changes in structure and species composition are possible, including conversion of rainforest to woodland, woodlands to shrublands and forblands (grasslands); loss of sphagnum bogs; and so on. Change in some wetter ecosystems will presumably be gradual with incremental impacts of increased fire in adjacent ecosystems. Fire intolerant species will be particularly vulnerable. However, many fire adapted species and ecosystems will also decline with increases in frequency, extent and severity and changes in fire season. Human responses (increased hazard reduction activities) may be more important than the direct changes in some regions. Some regions will see reduced fire risk due to slower growth rates or increased moisture.

New Species

There are likely to be many changes in species composition of communities and ecosystems as a result of climate change; a special instance will be the arrival of native and exotic species that are new to a region. Weeds and opportunistic species are expected to have more opportunity to establish due to both increased (changed) disturbance (creating dispersal and establishment opportunities) and changed growing conditions being less suitable for local species (at the extreme through the creation of "vacant niches" either because they are novel or because there is a delay or absence of local species distributions expanding as niches move). Agricultural and garden species and weeds are likely to be major sources of new species, with previously benign species possibly becoming invasive. Advent of "water-wise" gardens may yield a new generation of weeds. As well as the classic expected upward and pole-ward movement of species, different types of changes may favour different new species. For example: disturbance-regime specialists; species responding to particular growing conditions (e.g. stress tolerators in drying regions) or growing seasons which may change as a result of seasonal rainfall changes, temperature increases and possibly CO_2 changes (e.g. winter annuals, C_4 grasses, summer legumes); changed runoff and hydrology may favour or disadvantage wetland species; and frost sensitive species. The extent of habitat connectivity may affect the rate at which new species arrive, with more fragmented landscapes *in some situations* being more resistant to arrival of new species; they may also increase vulnerability to colonisation by weeds. While both native and exotic species will extend their distributions, exotics weeds with high seed dispersal, broad ecological tolerances and proximity to vectors are likely to dominate in many regions. However, if it becomes particularly arid native species may be more favoured. Increases in societal responses to fire, drought and flood are likely to increase the spread of species at times when establishment conditions for new species may be particularly favourable, i.e. at times of ecological release.

Some new species may be essentially benign; others may have a transforming impact on other species, e.g. new herbivores or predators; this will be largely unpredictable. This assessment focuses on opportunity and potential for new species to establish, not their impact.

Landuse change

Some regions will see widespread changes in landuse in response to climate change and other drivers. There will be changes in agriculture, forestry, tourism and patterns of urban development, and probably demand for more dams to secure urban water supplies. The changes will often lead to loss and fragmentation of habitat, or added pressure (e.g. with skiing progressively replaced by summer recreation of all kinds in the alps). Some changes may reduce pressure on biodiversity. For example, a shift in development away from immediate coastlines, in anticipation of rising sea level, could favour dune and salt marsh ecosystems; and abandonment of cropping may enable greater management for biodiversity conservation in semi-arid areas.

Many different responses might occur in agriculture with changes in CO_2, temperature, water availability, frost, heat stress, pasture productivity, weeds, disease prevalence, labour availability and so on. Decreases in crop productivity (e.g. with increased dryness) will lead to conversions to annual exotic pastures and complete abandonment in marginal areas. Changes in seasonality will lead to changes in varieties, crops and farming systems; e.g. summer cropping moving south. Increases in productivity (rainfall, longer season, fewer frosts) will lead to increases in cropping in some areas. Likewise increases in intensity of pastures would lead to some loss of native diversity. In southern Australia, reductions in water availability (both natural and via allocations) will see some irrigation areas shrink or change crops, possibly with more water becoming available for the environment. Increases in water use efficiency of irrigation systems however are likely to reduce return flows decreasing environmental flows. Reductions in pasture productivity in semi-arid areas are of particular concern as failure to concomitantly reduce grazing pressure could rapidly lead to large-scale degradation. Another major threat is the potential conversion of large areas of permanent pastures in the higher rainfall areas of southern Australia to cropping as water availability reduces (reducing water logging). These areas are often cleared (hence not protected by native vegetation regulations) but have high habitat value for ground feeding and nesting birds. Expanding urban areas will put pressure on peri-urban food production, both increasing demand for food and pushing production further out. There is also potential for increased intensification of agriculture, including expanded irrigation, in northern Australia, however considerable constraints will remain (unsuitable topography, remoteness, pests) if not intensify (heat stress and discomfort) with climate change. Possible increasing demand for biofuels could enable changes away from annual/exotic crops and pasture in some areas (e.g. to mallee cropping), or facilitate expansion/delay retreat of cropping (e.g. sugar production) in other areas. While remnant vegetation is largely protected by tree clearing legislation and most changes should be restricted to agricultural areas, less intensively managed buffers, scattered small woody remnants and native grasses might be lost.

Water

Changes in water availability are strongly related to changes in rainfall and temperature dynamics affecting runoff, potential evaporation, soil moisture dynamics and seasonality, and amount of flow. Natural stream flows and storage volumes will be reduced. The buffering effect of flows will be affected due to loss of snow mass, bogs, fens etc. There are likely to be major stresses on water extraction and storage, with new and bigger dams required, leading to more competition for water. Rivers and wetlands that are usually perennial will dry out more frequently and for longer periods, resulting in many impacts on biodiversity aquatic, riparian and terrestrial biodiversity (including resident and migratory species). The reduced/changed ground and surface water would have a big impact on agriculture and native fauna. This will also affect flood plain and ephemeral wetland species (e.g. red gums) through less frequent floods (in many places). There will also be an impact of low rainfall coming into summer and less soil moisture storage. In northern Australia, there is likely to be more flooding and potential change in timing of the wet season. The interaction between ground water and surface water and vegetation are ecologically very important and changes to these interactions could be critical in many systems, however knowledge is very limited.

Growing season

Changes in growing season are one of the main focuses of this assessment. Seasonal patterns and limits to growth are derived (defined) by the Hobbs & McIntyre (2005) zones, which are derived from modelled growth responses by Hutchinson *et al*. (2005). Projected changes in seasonal temperature and moisture are compared to drivers/limits to growth to assess likely seasonal growth responses, including more or less growth or changes in key growing seasons. The assessments are all qualitative, quantitative modelling is planned in the future. Where winter temperature (but not moisture) limits growth, increasing temperatures are likely to increase winter growth (until moisture becomes limiting); where moisture availability limits growth, reduced rainfall will decrease growth and increased rainfall may increase growth (depending on temperature impacts on evaporation). Impacts of CO_2 will be critical in determining actual growth responses. Frost impacts on growing season are also considered.

Vegetation structure

Fire could have a major impact on vegetation structure, through drying wetlands, bogs, fens and influencing the elevation of the tree line. If fires are more frequent or hotter, then many ecosystem transitions are likely, including from rainforests to savannah, forest to woodland, and shrublands to grasslands, and will be fewer old growth forests. General drying will lead to similar transitions, including conversion of woodland to shrublands and a general weakening of perennial grasses. Changes in agricultural land use will also lead to landscape scale vegetation changes. Transition from cropping and grazing would probably need facilitation if woodland and native grassland are to be re-established quickly. There will also be some direct pressures from habitat clearing, possibly on a small scale but with large aggregate impact. Altitudinal sorting may affect some species. Cyclones may reduce the distributions of tree ages/sizes in rainforest but otherwise vegetation adapted unless new weeds truncate successional processes. Changes in disturbance regimes may facilitate increases in some functional types, for example vines following increased storm damage, and resprouting species following more frequent fires.

Composition

The composition of ecosystems and communities will be driven by changes in fire regimes, new species (exotics and natural spread of natives), drying out of wet areas, change from summer to winter grasses, change in mix of C_3/C_4 grasses and northern species moving south.

There will be losses of alpine specialists and bog-dependent species, as well as loss of many marginal native species due to habitat fragmentation and inability to adjust distributions. Drier autumns and winters could disadvantage winter growing annual weeds in some regions. More summer rain could advantage natives such as dominant C_4 species and native legumes (warm season growers). If it gets significantly more arid, native species will survive better than most exotics. High levels of fragmentation would lead to many local extinctions of native species. Coastal vegetation is especially at risk from all these plus sea level rising.

There could be significant reductions of wet sclerophyll eucalypts (alpine ash, mountain ash) if increased fire frequency results in burning before sexual maturity.

Synthesis – key issues

These climate change impacts clearly combine with other (non-climate-related) environmental stresses on biodiversity, and are affected by feedbacks from population and ecosystem impacts (e.g. affecting nutrient cycling, hydrology and flammability). There will be direct changes to organisms arising from environmental changes; they take in physiological and behavioural changes and include changes in the timing of lifecycle events (phenology). Following on from this will be changes in breeding, establishment, growth, competition, and mortality related to climate change directly, but also modified by changes in competition, food, habitat and predation. This will lead to changes in abundance and distribution. There will be an overall shuffling of species through low altitude species moving higher, high altitude species lost, inland species moving towards coast, western species moving east, but predominantly species moving south. There will be losses of some native species, especially in more fragmented southern regions, but some areas have resilient soils and vegetation so changes may not be too dramatic. Changes in seasonality will affect biodiversity and triggers for lifecycle events (eg crocodile breeding, turtle gender), with changes in the identity, composition, structure and function of assemblages and ecosystems.

APPENDIX 2. INFORMATION USED IN ASSESSING BIODIVERSITY IMPACTS BY AGRO-CLIMATIC ZONE

Preliminary assessments were conducted of the impacts of climate change on biodiversity in the ten agro-climate zones of Australia (based on Hobbs & McIntyre 2005). The methods are described and results summaries in Section 5. Provided here is a description of the zone and its landscape characteristics and processes; descriptions of potential changes in environmental characteristics, key threats, and biodiversity responses; followed by a summary of the key issues for biodiversity resulting from changes to seasonal growth and other ecosystem processes due to climate. Refer also to the information presented in Appendix 1.

Cold-wet

Current	Descrip-tion	Biome	Cold forest and alpine grassland
		Climate & growth	Cold winters with short summers warm enough to support significant growth.
		Where	Tasmanian highlands and Victorian and NSW alpine areas
	Landscape characteristics/ processes	Ecosystem function	Seasonally cold, snow, high rainfall, altitude significant, seasonal migration
		Habitat diversity	Very diverse, topographical, complex. Alpine meadows, shrublands, woodlands, forest to rainforest in Tas.
		Climate extremes	Cold, snow, frost, wet spring, summer water stress in some areas
		Disturbance	Very infrequent fire, forestry, some grazing in lower areas
		Agric	Little grazing; too wet and steep for cropping
		Habitat loss	Resorts, tourism, recreation, dams, little land clearing,
		Ground water	Not important?
		Surface water	Snow in winter and bogs and fens store much water providing year round flows; wetlands and significant rivers, recreation water harvesting
Future	Environmental change	Temperature	Less snow cover, longer growing season, fewer frosts, more summer water stress?
		Rainfall	Tas: increased rainfall, especially in winter. Alps: drier, especially winter and spring
		CO2	
		Storms	
		Sea level	
	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Inc fuel and fire weather; more intense, more frequent fires. Major issue as fire currently infrequent; altered structure and composition. Impact on snow gum forest and woodlands; possible conversion of woodlands to shrublands & forblands (grassland). Decrease in sphagnum bogs leading to changed water flows (more in spring, less in summer). Fire management impacts may be significant.
		New Species *new occurrences of native and exotic species*	Improved growing and establishment conditions for non-alpine species; more over wintering spp; elevational range expansion. Increased herbivore and carnivore mammal activity (brumbies, wallabies, rabbits, cats, foxes). Escape from domestic gardens and transport from lower altitudes.
		Landuse change *due to climate change*	Forestry, grazing change? Increased snow making. Increased summer tourism and recreation with proportionately greater impact than skiing due to buffering by snow. Possibly more dams. Overall some increased fragmentation due to continued development, golf courses, tennis courts etc.
		Water	Reduced buffering of flows due to loss of snow, bogs, fens. More spring, less summer, autumn flows. Possibly reduced flows for irrigation and hydropower and other down stream water users; impact on Snowy River flows. Impact on aquatic ecosystems.
	Biodiversity response	Growing season	Extend growing season, or summer possibly too hot and dry in some areas.
		Vegetation structure	Vegetation thickening due to CO2 and longer growing season; rising treelines. But fire increased fire will have a major impact, favouring shrubs and forbs/grasses. Drying of wetlands, bogs, fens.
		Composition	Reduction and local loss of some fire sensitive species. Many new (low land) species Eventual loss of some alpine specialists; reduction in alpine bog-dependent species. Increased weediness as climate becomes more temperate and colonisers are transported in.
		Other	Loss of insulation and habitat provided by snow. Seasonality and variability of snow changes will be important for some species especially migrants. Variable changes in timing of some seasonal migrants.
Key Priorities/ Issues			Reduced snow cover and duration. Upward migration of species and ecosystems: low altitude species moving to higher elevations, some higher elevation species lost. Drying of wetland areas. Change in tourism and recreation demands. Fire impacts on forests, woodlands.

Temperate cool-season wet

Current	Description	Biome	Temperate moist forest
		Climate & growth	Cool wet climate; Moisture Index high in winter-spring, mod. In summer; Growth Index high in spring
		Where	Tasmanian lowlands, southern, central and eastern Victoria; southern and northern NSW tablelands.
	Landscape characteristics/ processes	Ecosystem function	Cool, high rainfall, high winter-spring growth, regular fire
		Habitat diversity	Diverse; topographically diverse: high tablelands to coast. Large areas of forest, woodland, and smaller areas of grassland.
		Climate extremes	Cool wet winter, frost. Hot summer; drought.
		Disturbance	Regular drought and fire. Extensively cleared and fertilised for grazing; forestry, horticulture; regular fire; local salinity
		Agric	Forestry; sheep, beef, dairy; horticulture; cropping.
		Habitat loss	Heavily cleared for pasture and cropping; urban development; forestry
		Ground water	Probably important locally.
		Surface water	Very important urban water supply area; many wetlands and rivers. Many farm dams.
Future	Environmental change	Temperature	Warmer, fewer frosts
		Rainfall	Drier winter spring, seasonality of moisture will be important
		CO2	
		Storms	
		Sea level	Increased sea level, coastal inundation, mangroves, coastal wetlands affected by salt intrusion
	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Inc fire weather; possibly less fuel production. Probably more frequent and maybe more intense fires, but impact of changed fuel production unknown. Increased fire will be a major issue, both for currently fire-prone and not-fire-prone areas, affecting structure, function and composition. Dry winters may make fuel-reduction burns more difficult and less effective. The region has significant fire management, how it adapts and responds will be important.
		New Species *new occurrences of native and exotic species*	Many source of new species from agric and gardens. Increased fire management will have potential to spread and encourage establishment. More summer growing natives such as dominant C4 species & native legumes (warm season growers). More frost sensitive species. Drier autumns & winters could disadvantage winter growing annuals, which are major category of weed in this region.
		Landuse change *due to climate change*	Conversion of permanent pastures (with native component) to cropping and annual pasture a major threat (especially to grassland depended birds) with reduced rainfall and water logging potential. Possibly some abandonment of cropping in drier and marginal areas. Very little further clearing as all native vegetation now protected. Potential increased intensification of pastures & some loss of diversity as a result. Significant impact of forestry: fire will be an increasing threat to wet sclerophyll eucalypts (alpine ash, mountain ash) forest assets, and conservation value of forests increased due to threat of increased fire frequency to forests in conservation reserves; and issue for water catchments.
		Water	Significant reductions in stream flows; usually perennial rivers & wetlands may be dry periodically or for longer; impact on wetland and riparian ecosystems; less frequent floods (red gums etc); impact on migratory species? More conversion of wetlands, floodplains to cropping. Major stress on water extraction & storage; new dams? Less filling of farm dams (although more intense rainfall may favour runoff and dam filing). More competition for water.
	Biodiversity response	Growing season	Mixed, growing season and overall productivity will depend on interaction of temperature, rainfall and CO2. Change in seasonality of moisture will be important. Possibly earlier-longer growing season; but reduced summer growth due to higher temp (moisture stress?), and possible reduced winter growth due to decreased rainfall.
		Vegetation structure	Fewer old growth wet sclerophyll forests if fire frequency greater than period required for flowering; loss of tall old trees.
		Composition	Loss of fire sensitive species. Loss of some wetland species. Drier autumns & winters could disadvantage winter growing annuals. New summer growing (C4) species.
		Other	Possible loss of marginal native species due to habitat fragmentation & inability to adjust ranges. Largely disconnected from most semi arid summer growing regions.
Key Priorities/ Issues			Change in fire frequency and intensity affecting structure and composition. Changed growing season and reduced (?) growth. New species will establish (especially weeds) from agriculture and gardens. Change in seasonality of rainfall will affect winter annuals, but disconnected from most sources of summer growing semi-arid species. Conversion of grazing into cropping, but some abandonment of cropping because too dry. Fragmentation limits distribution changes. Major water extraction issues. Drying out of wetlands.

Mediterranean

Current	Description	Biome	Mediterranean woodland, heaths, open forests.
		Climate & growth	Warm climate; Moisture Index high in winter, low in summer; Growth Index moderate in winter. Peak growth winter and spring.
		Where	Southwest WA, southern SA, north- west Victoria, southern NSW.
	Landscape characteristics/ processes	Ecosystem function	Winter / spring growth; warm summer; regular fire.
		Habitat diversity	Local topography but largely flat. Soil and biogeog history diversity. Open forest, woodland, mallee, heath.
		Climate extremes	Cool wet winters, frost; hot summers. Drought.
		Disturbance	Regular drought and fire. Highly disturbed. Extensively cleared and fertilised for cropping and grazing. Native vegetation grazed. Many exotic species. Salinity and acidification.
		Agric	Cropping, sheep, beef horticulture, dairy, irrigation; forestry.
		Habitat loss	Heavily cleared and fragmented; grazing, nutrients; urban development.
		Ground water	Locally very important for some ecosystems, agriculture, base flows
		Surface water	Many wetlands, semi-seasonal rivers; farm dams important. Soil water important for spring growth.
Future	Environmental change	Temperature	Reduced summer growth; more winter growth; fewer frosts, longer growth.
		Rainfall	Reduced winter rainfall that is critical for annual growth
		CO2	
		Storms	
		Sea level	Increased sea level, coastal inundation, mangroves, coastal wetlands affected by salt intrusion
	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Increased fire weather. Probably more frequent and maybe more intense fires. Many fire adapted ecosystems, but increased frequency and changed intensity and seasonality likely to eliminate or reduce many species. Fire intolerant ecosystems vulnerable. Affecting structure, function and composition. Changes in growth and fuel loads unknown – reduced growth would decrease importance of fires (as in semi-arid systems). The region has significant fire management, how it adapts and responds to changing fire regimes will be important.
		New Species *new occurrences of native and exotic species*	Many source of new species from agric and gardens. Increased fire management will have potential to spread and encourage weed establishment. More frost sensitive species. Fragmentation and fertiliser history provides more opportunities for invasion. If it gets really arid, natives will survive better.
		Landuse change *due to climate change*	Extensive change due to drying, increased variable and opportunistic cropping, reversion to annual pastures, and retirement / abandonment of cropping; many other drivers. Increased cropping in areas that become more suitable (e.g. on soils prone to water logging). Irrigation areas will shrink or change crops. Grazing pressure likely to remain high, unknown impact of increased climate variation.
		Water	Significant reductions in stream flows; usually perennial rivers & wetlands may be dry periodically or for longer; impact on wetland and riparian ecosystems; less frequent floods (red gums etc); impact on migratory species? More conversion of wetlands, floodplains to cropping. Major stress on water extraction & storage; new dams? Less filling of farm dams (although more intense rainfall may favour runoff and dam filing). More competition for water.
	Biodiversity response	Growing season	Possibly earlier-longer growing season – earlier spring flush; but reduced growth in summer due to inc temp and winter-spring due to less rain.
		Vegetation structure	General response to drying. Forest to woodland, woodland to shrublands, shrubs to grassland. Response to increased variation? General weakening of perennial grasses?
		Composition	Loss of fire sensitive species. Loss of some wetland species. More weeds and opportunists due to increased variation, fire and general churn. More semi-arid and inland species moving coastward.
		Other	Possibly significant loss of many restricted species in SW fragmented landscapes, although tolerances largely unknown. Region heading towards semi-arid as summer rainfall would have to increase a lot to get an effective growth season in summer due to the high temperatures.
Key Priorities/ Issues			Increased fire frequency and changed seasonality and intensity. Change in vegetation structure from forest to woodland, from woodland to shrubland and grasslands. Significant landuse changes, some agriculture retirement/abandonment, conversion of pasture and wetlands to crop in wetter areas. Increased variability, more opportunists, semi-arid and weedy species. Impact on wetlands and rivers, and water extraction - dams, groundwater.

Temperate, subhumid

Current	Description	Biome	Temperate subhumid woodland
		Climate & growth	Cool winter and moisture limiting summer. Moisture Index moderate to high year-round; Growth Index high in spring to autumn. Most plant growth in summer, although moisture limited; temperature limits growth in winter.
		Where	NSW western slopes
	Landscape characteristics/ processes	Ecosystem function	Summer growth dominant (but moisture limited); winter growth temp limited.
		Habitat diversity	Continuous topographic diversity; rolling hills, gullies, gorges; many microclimates. Biogeographic history. Mainly woodlands, some grasslands and forests.
		Climate extremes	Cool/cold winter, frosts; warm summer; drought.
		Disturbance	Drought & infreq. fire; extensively cleared & fertilised in parts; grazing; salinity, acidification, erosion
		Agric	Intensive grazing, summer and winter cropping; irrigation
		Habitat loss	Much clearing and fragmentation, but restricted by topography and soils. Grazing, nutrients.
		Ground water	?
		Surface water	Many wetlands, permanent rivers; farm dams important. Soil water important for spring growth.
Future	Environmental change	Temperature	Hotter summer. Warmer winter, fewer frosts, increased winter growth.
		Rainfall	Less winter & spring; more autumn & summer -> increased summer growth & decr. winter growth
		CO2	
		Storms	
		Sea level	
	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Low natural fire freq.; possibly more fuel & increased fire weather, big impact of increased frequency, intensity & extent; fire intolerant species & ecosystems vulnerable. Fire management impacts may be significant.
		New Species *new occurrences of native and exotic species*	Changes will favour new frost sensitive species, winter active species & possibly summer opportunists. Many source of new species from agric & gardens. Also, seasonally, species from west, north and east may be favoured. Increased fire management will have potential to spread & encourage weed establishment. Fragmentation & fertiliser history provides more opportunities for invasion. Lots of opportunities for weed invasions but may be offset by increasing selection for stress-tolerators (> representation by natives).
		Landuse change *due to climate change*	Suitability for different agricultural activities could change considerably, especially with warmer winters and possibly wetter summers. Some pasture areas may become more suitable for winter and/or summer cropping, however this may be restricted by soil or topography limitations. Drying wetlands maybe cropped, some are protected. Other areas may become less suitable for cropping with conversion to annual pasture and intensive grazing. Similarly change in seasonality of cropping is likely. Climate is one of many drivers of land use change.
		Water	This is an important catchment zone, decreased winter rainfall and increased growth in winter may lead to significant reductions in stream flows. Increased summer rainfall may partly alleviate this, or albeit leading to changes in seasonality of flows. Reduced winter, spring rainfall we lead to less soil water coming into summer growing season, again this may be alleviated by increase summer-autumn rain.
	Biodiversity response	Growing season	At least initially, probable increase in annual productivity and change from summer to year round growth due to increased winter temperatures (moisture is currently not limiting in winter) and summer rainfall (when moisture does limit growth) Details will depend on interaction of temperature, rainfall and CO2. Change in seasonality of moisture will be important and lead to vegetation and species responses.
		Vegetation structure	Increased growth and change in seasonality are likely to see thickening of vegetation, at least initially. However, increased fire frequency and possibly severity will interact will also affect vegetation structure. If agricultural land is retired, they may be opportunity to re-establish woodland, native grassland.
		Composition	Many changes possible. Increase in winter grasses, species favoured by year-round growth and possibly species favoured by summer storms e.g. C4 grasses. Considerable species mixing is possible with western, northern and eastern species being favoured in various seasons.
		Other	Fragmentation will limit the establishment of new species and movement of existing ones; however, high landscape diversity provides many opportunities for suitable micro-habitats.
Key Priorities/ Issues			Increase in growth and growing season, at least initially, will lead to changes in structure and provides opportunity for many new species, (winter growing grasses, year round growth, summer active species). Increases in fire frequency and intensity will be significant, leading to greater fire management and weed establishment. Intensification of land use possible, constraints on changes unknown; changes in crops and seasonality likely. Potentially some crop-pasture abandonment. Stress on water resources likely, possibly leading to demand for more storages.

Subtropical subhumid

Current	Description	Biome	Brigalow belt. Woodland
		Climate & growth	Mild winter with Moisture Index and Growth Index moderate year-round. Growth limited by moisture.
		Where	North-west plains of NSW and QLD Brigalow Belt.
	Landscape characteristics/ processes	Ecosystem function	All year growth limited by water. Nutrient issues?? C3 and C4???
		Habitat diversity	Elevated plains and hills; gorges in some areas. Diverse soil types. Mainly eucalypt and acacia woodlands, some grasslands and forests.
		Climate extremes	Prone to floods and drought periods.
		Disturbance	Drought and storms. Extensively cleared and fertilised for cropping and grazing. Salinity, acidification, erosion.
		Agric	Summer and winter crops, pastures, irrigation, forestry
		Habitat loss	Heavily cleared and fragmented. Grazing in some native vegetation.
		Ground water	Locally important in some areas
		Surface water	Important catchment area; many rivers; farm dams; soil water holding important for seasonal growth
Future	Environmental change	Temperature	Warmer, fewer frosts; increased heat stress
		Rainfall	Wetter summer likely in most of region; drier winter and spring.
		CO_2	
		Storms	More intense, more damage, more flooding, more erosion
		Sea level	
	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Fire currently not really important in this region. More extreme fire weather likely and possibly increased summer fuel production. Most likely to see an increase in late season Autumn. Frequency, seasonality and intensity will depend on litter growth and curing.
		New Species *new occurrences of native and exotic species*	Changes will favour summer growing (possibly more tropical) species. Many sources of new species from agric and human settlement, although warm season natives should continue to be maintained.
		Landuse change *due to climate change*	Change in seasonality toward more summer cropping. Winter crops and pastures decreasingly productive. Conversion back to pasture and abandonment of some agric lands increasingly likely. Remnant vegetation largely protected so changes should mostly be within agricultural areas. Likely to be more summer cropping & reduced winter cropping.
		Water	Runoff will become increasingly summer dominated and probably decrease, although increases in intense rainfall will favour runoff. Reduced winter rain will see less carry over to summer growing season. Intense rainfall could impact cropping areas, but topography relatively gentle in many areas.
	Biodiversity response	Growing season	Shift to dominance of summer growth; and possible decrease in growth overall, although CO_2 interactions important.
		Vegetation structure	Not clear. Likely to stay as woodlands in most areas.
		Composition	Increase in tropical / summer growing species. Some fire sensitive species will be affected. Decrease and possibly change in composition of winter active species.
		Other	A change in the extensive acacia woodlands could significantly alter nutrient flows. Soils are pretty good & will put up with more abuse than the southern soils.
Key Priorities/ Issues			Some increases in summer active species and declines in winter species. Increased fire frequency may become an issue, with more litter and hotter temperatures, but offset by wetter summer. Big issues for agricultural and human settlement, changes in landuse; seasonal changes, possible conversion of crop to grazing and abandonment. Changes in seasonality of river flows; important catchment with increased demand for more dams.

Subtropical moist

Current	Description	Biome	Subtropical moist forest
		Climate & growth	Moisture Index and Growth Index moderate to high year-round. Both indices are lower in winter in southern regions and lower in spring in northern regions.
		Where	Coastal southern-QLD and NSW (climate is more temperate in southern NSW)
	Landscape characteristics/ processes	Ecosystem function	Year round growth
		Habitat diversity	High landscape diversity; coastal plains and hills. Mainly Eucalypt forest; regionally rainforest woodland, and heath. Mangroves, salt marshes and wetlands along the coast.
		Climate extremes	Periods of high rainfall and drought
		Disturbance	Urban development, cropping, grazing, fire, drought, flood
		Agric	Horticulture, intensive grazing, forestry
		Habitat loss	Urban development, cropping, grazing, forestry
		Ground water	Locally important in some areas
		Surface water	Many perennial wetlands, and rivers, flows very variable with local rainfall in relatively small catchments.
	Environmental change	Temperature	Increasing but less than inland.
		Rainfall	Increased summer and autumn rainfall
		CO2	
		Storms	More intense rainfall and storms, more damage, more flooding, storm surge
		Sea level	Increased sea level, coastal inundation, mangroves, coast wetlands affected by salt intrusion
Future	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Many fire-adapted ecosystems, but also many fire sensitive ones (wet sclerophyll and rainforest) in gullies and other wetter microhabitats. Increased fire frequency, intensity and extent likely, due to dryness but no reduction in fuel. Impact expected on both fire adapted (due to "excessive" frequency) and fire sensitive species. Societal reaction to increases risk will be important.
		New Species *new occurrences of native and exotic species*	Lots of potential due to agric and human settlement, fragmentation and fertiliser history. Local and exotic species expected to re-sort with improved growing conditions, but no strong seasonal change expected. Increased fire management will have potential to spread and encourage establishment. Urban pressure will increase weeds especially through more "water-wise" garden weeds.
		Landuse change *due to climate change*	Urban development to continue: more vegetation clearing for suburbs and associated fire protection. Possibly more pressure for food production, conversion of pasture to horticulture? Forestry practices may change with increased fire risk; conservation value of forests will increase. Coastal ecological communities under threat from societal responses to sea level rise: sea walls, etc; and salt marshes etc unable to migrate inland due to development.
		Water	More local flooding due to increased intense rainfall. More frequent droughts with increased urban development would pose additional threat to water security, and aquatic ecosystems.
	Biodiversity response	Growing season	Increased growth likely. Possibly some relative increase in summer growth in southern part.
		Vegetation structure	Not clear. Increased rainfall and growth may favour forest and wetter species, but this will be countered by increased fire frequency.
		Composition	Much local species changes aided by high species diversity and habitat diversity. Some fire sensitive and fire-adapted species will be affected. Northern species moving south, but restricted by high levels of fragmentation and habitat modification.
		Other	
Key Priorities/ Issues			Many fire-adapted ecosystems, but increases in fire frequency, intensity and extent possible: rainforests and wet sclerophyll at risk. Big issues for agricultural and human settlement. High level of fragmentation with some level of re-sorting will lead to local extinctions. Sea level rising important for mangroves, salt marshes, coastal wetlands.

Tropical warm-season wet

Current	Descrip-tion	Biome	Tropical savannah
		Climate & growth	Moisture Index and Growth Index high in warm season, very low in cool season.
		Where	North-west WA, northern NT, and Cape York Peninsula.
	Landscape characteristics/ processes	Ecosystem function	Seasonal wet/dry; local seasonal inundation for some regions; 1-3 yearly cool fire; fast draining (growth needs regular water)
		Habitat diversity	Medium scale topographic; many drainage lines, hills, escarpment, soils. Savannah, woodlands and grasslands; Forests and pockets of rainforest. Extensive mangroves, salt marshes and wetlands along the coast.
		Climate extremes	Annual, cycle of hot and very wet, warm and very dry; but some inter-annual variation.
		Disturbance	Cyclones. Flooding and fire are very regular. Land clearing for grazing and some cropping.
		Agric	Extensive grazing; some irrigation.
		Habitat loss	Grazing; new pasture species; changed fire regimes; small scale clearing
		Ground water	Very important locally in dry
		Surface water	Dominant driver, timing and duration important; supplies water to northern arid zone;
Future	Environmental change	Temperature	Hotter but not as much as inland. Increased heat stress
		Rainfall	Increase in wet season (summer autumn). [Trend for inc rain in west observed but not consistent with scenarios.]
		CO2	
		Storms	More storm disturbance
		Sea level	Increased sea level, coastal inundation, mangroves, coastal wetlands and flood plains affected by salt intrusion
	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Flora/fauna well adapted to fire, but sensitive to fire regime. Change in seasonality, severity (hotter earlier), frequency (less in some areas) and extent of fire due to climate, agricultural practices (more flammable pasture species) and species, and reduced aboriginal burning.
		New Species *new occurrences of native and exotic species*	Scope for tropical exotics from North; high dispersal in wet, more establishment from more intense storms and possibly changing fire regimes, but veg largely intact so less vulnerable to invasion than south. Also coastal movements more possible due to limited development & ability for zones to move; however saltwater incursions into freshwater swamps likely to be significant. New more-flammable pasture species a major threat.
		Landuse change *due to climate change*	Big changes probably unlikely. But many drivers: intensification of pasture; tropical biofuels; Increased heat stress, less attractive to people, changed animal productivity; more intensification associated with the Ord, distance to markets; political push for major increase in northern agric partly due to water shortages in south.
		Water	Saltwater intrusion into freshwater wetlands
	Biodiversity response	Growing season	Possibly reduced growth due to increased temperature. Any seasonal and inter-annual changes in rainfall would be significant.
		Vegetation structure	Changed fire regimes (hotter, earlier and less frequent due to pastoral activity and de-population) will be the major drivers: gradually decreasing rainforest as fire intrudes and reducing tree cover in woodlands. More intense storms may favour some vegetation types: e.g. vines over trees.
		Composition	Pasture species, other agricultural weeds. More northern species.
		Other	Impacts expected on tropical animals whose breeding is affected by seasonal weather (e.g. crocodiles and turtles)
Key Priorities/ Issues			Change in fire seasonality and frequency. Potential for spread of exotics from north: high dispersal of exotics during wet season. More intense storms. Saltwater incursions into freshwater swamps. Push for agriculture in north but limitations exist.

Tropical warm-season moist

Current	Description	Biome	Tropical forest and woodland
		Climate & growth	Characterized by a long growing season and a cooler dry season than the tropical savannas. Moisture is the main limiting factor to growth and the Growth Index is lowest in spring.
		Where	Coast and hinterland areas of Queensland (subtropical in southern QLD)
	Landscape characteristics/ processes	Ecosystem function	Seasonal wet/dry
		Habitat diversity	Large-scale topography: coastal, plains, slopes to tablelands, tropical mountains in north; meso-scale climate; biogeog history. Mainly eucalyptus woodlands and forests. Regions of rainforest and acacia forest.
		Climate extremes	Annual cycle of hot and wet; moderate and dry.
		Disturbance	Cyclones. Local flooding. Land clearing for cropping and urban development on coast, and grazing. Fire infrequent.
		Agric	Sugar, horticulture, other cropping, intensive grazing.
		Habitat loss	Much clearing, but limited by topography and soils. Drainage of wetlands. Grazing.
		Ground water	Very important locally in dry
		Surface water	Very important. Many high volume tropical rivers.
Future	Environmental change	Temperature	Hotter but not as much as inland. Increased heat stress
		Rainfall	Decreased winter and spring rainfall leading to increased seasonality.
		CO2	
		Storms	More intense cyclones and storms, more damage, more flooding, more erosion, cyclones moving south.
		Sea level	Increased sea level, coastal inundation, mangroves, coastal wetlands, flood plains affected by salt intrusion
	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Fire currently infrequent. Drier winter and spring likely to increase frequency and intensity of fires and possibly change season. Increase would be a major change to floristics, structure and function, especially in rainforests and wet forests.
		New Species *new occurrences of native and exotic species*	Reasonable potential for new species to arrive and establish due to proximity to northern tropics, extent of disturbance by agric and human settlements; increased storm intensity; increased fires. Increased fire and storm management likely to be an issue, spreading seeds etc at ideal time for establishment.
		Landuse change *due to climate change*	Big changes probably unlikely. But many drivers: intensification of pasture inland; expansion of horticulture, possibly increased sugar and other tropical crops for biofuels; increased heat stress, changed animal productivity; political push for major increase in northern agric partly due to water shortages in south. Urbanisation and tourism increase.
		Water	Saltwater intrusion into freshwater wetlands and ground water. Decreased winter spring flows.
	Biodiversity response	Growing season	Growth becoming more strongly seasonal: less winter and spring growth.
		Vegetation structure	Possibly rainforest decline due to drier conditions (leading towards savannah), fire becoming more frequent and more intense storms. Direct clearing pressure (small scale but huge aggregate impact).
		Composition	Some northern species moving south (but it is drier). Species expected to change locally & altitudinal sorting will affect some species. Many endemic species restricted to tops of tropical mountains may be severely affected, but tolerance largely unknown, probably will depend critically on uncertain rainfall changes.
		Other	Impacts expected on tropical animals whose breeding is affected by seasonal weather (e.g. crocodiles and turtles)
Key Priorities/ Issues			Increasing fire will become a major issue for composition, structure and function. Increase pressure from agriculture and human settlement. More intense cyclones leading to structural change and establishment opportunities for weeds, but human-induced weeds important. Rainforest especially affected by fire, seasonal drying, and more intense storms. Expansion of horticulture and possibly sugar and biofuels. Species near tops of mountains may be severely affected, but tolerance largely unknown.

Tropical wet

Current	Descrip-tion	Biome	Tropical rainforest
		Climate & growth	Moisture Index and Growth Index high all year, J1 has short dry season
		Where	Limited areas on the east coast of northern QLD
	Landscape characteristics/ processes	Ecosystem function	Wet, year round growth. Tropical rainforest.
		Habitat diversity	Medium scale topography: coastal plains, hills, tropical mountains in south. Rainforest, eucalypt forest. Extensive mangroves, salt marshes and wetlands along the coast.
		Climate extremes	Hot and wet summer.
		Disturbance	Cyclones. Fire very infrequent.
		Agric	Grazing in places.
		Habitat loss	Grazing, fire intrusion.
		Ground water	
		Surface water	A dominant driver.
Future	Environmental change	Temperature	Hotter, not as much as inland. Increase heat stress
		Rainfall	Possible decrease in autumn, winter and spring rainfall, leading to increase in seasonality.
		CO_2	
		Storms	More intense cyclones, more damage, more flooding, storm surge
		Sea level	Increased sea level, coastal inundation, mangroves, coastal wetlands and flood plains
	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Not currently fire prone. Warming and seasonal drying and changes in surrounding veg likely to lead to inc risk of fire encroachment. Even a small increase in fire would be a major change to floristics, structure and function. Likely to be gradual erosion of rainforest from fire in surrounding vegetation.
		New Species *new occurrences of native and exotic species*	Potential for new species to arrive due to proximity to northern tropics, and increased storm damage, and fire, but other disturbance (agric and urban development) localised.
		Landuse change *due to climate change*	Big changes probably unlikely. But many drivers: intensification of pasture inland, facilitated by hotter fires in savannah and encroaching on rainforest, expansion of horticulture (?), possibly increased sugar and other tropical crops for biofuels. Increased tourism.
		Water	
	Biodiversity response	Growing season	Growth decreasing overall and becoming more strongly seasonal: less winter and spring growth.
		Vegetation structure	Structure could be affected by seasonal drying (opening veg), fire (ditto) and increased storm/cyclone intensity (early successional and vines), depending on frequency.
		Composition	Significant changes in floristics in fire affected areas. Late successional species may be affected by increased storm intensity. Many endemic species restricted to tops of tropical mountains may be severely affected, but tolerance largely unknown, probably will depend critically on uncertain rainfall changes.
		Other	Impacts expected on tropical animals whose breeding is affected by seasonal weather (e.g. crocodiles and turtles)
Key Priorities/ Issues			Increased risk of fire encroaching on rainforests, seasonal drying, affecting floristics, structure and function. Increased storm / cyclone intensity may change structure and favour some species (vines, early successional species). Threat to tropical mountain species. Higher altitude species.

Dry

Current	Description	Biome	Arid grassland and shrubland
		Climate & growth	Warm to hot and dry. Moisture Index and Growth Index low all year
		Where	Large central portion of the continent. Southern regions wetter in winter (E6) and northern regions wetter in summer (H)
	Landscape characteristics/ processes	Ecosystem function	Rainfall pulses, fire mosaics, grazing; mobile fauna; refuges
		Habitat diversity	Medium and fine scale topography (rocky ranges, low hills, ephemeral lakes/salt pans, as well as extensive areas of low relief); soils
		Climate extremes	Hot, dry, cold
		Disturbance	Fire, grazing, drought, flood; artificial water points supporting native and exotic grazers in low rainfall times
		Agric	Extensive grazing, large impact; very restricted irrigation
		Habitat loss	Degradation due to over-grazing, exotic species; change fire regimes.
		Ground water	Locally very important for flora and fauna, and people.
		Surface water	Periodic flooding. Waterholes critical for drought refuges
Future	Environmental change	Temperature	Greatest temperature increases will be in this zone. Increased heat and water stress. Most species cope with high temp, but tolerance to increased temperature unknown.
		Rainfall	Highly variable, may become more variable; little overall change in average annual rainfall. Increase in summer rainfall in eastern half; Increase in autumn rain in parts of south and west. Decrease in winter spring rain in south.
		CO_2	
		Storms	More variable and intense.
		Sea level	Increased sea level, coastal inundation, mangroves, coastal wetlands in west.
	Key changing threats	Fire: *intensity, frequency, seasonality, extent*	Fire very important, but infrequent due to slow growth. Change very dependent on changes in growth and grazing.
		New Species *new occurrences of native and exotic species*	More autumn rain may inc suitability to new species and allow northern species to move south.
		Landuse change *due to climate change*	Pastoralism may decline with increased temperature and variability. Human responses will be critical in avoiding overgrazing in less productive landscape. Abandonment of pastoralism in some areas.
		Water	Reduced ground and surface water would be big impact on agric and native flora and fauna. More intense rainfall may increase runoff and recharge, however increased temperature will increase evaporation.
	Biodiversity response	Growing season	Less winter growth. Autumn and summer growth will depend on interaction of increased temperature, rainfall and CO_2. Some change in seasonality but currently a very variable climate anyway.
		Vegetation structure	Not clear. Woodlands in west may be affected by drying in winter. Balance between climate and grazing changes will be critical.
		Composition	Loss of more heat sensitive species, but mediated by changes in rainfall. Possibly new pasture species. Possibly more stress tolerant species. Landscape relatively intact, so species re-assortment will be able to occur. Possible increase in tropical species to northern arid zone, and northern arid species to south with increased summer, autumn rainfall.
		Other	
Key Priorities/ Issues			Fire important but limited by growth and grazing, both of which are uncertain. More summer and autumn rain may increase suitability for new species from north and new pasture species. Potential for overgrazing high as productivity decreases. Pastoralism may decline and perhaps some retirement of drying areas. Reduced or changed ground and surface water would have big impact on agriculture and refuge-dependent native flora and fauna.

APPENDIX 3. DETAIL OF MODELS USED IN THE IBRA CLIMATE SCENARIO ANALYSIS

ECHAM5/MPI-OM Model

Host organisation
Max Planck Institute for Meteorology

Country of origin
Germany

Atmospheric and ocean model attributes
Atmosphere resolution: horizontal resolution 1.8° lat/long, approx 200 km between gridpoints, 31 vertical levels
Ocean: horizontal resolution 1.5° lat/long, 40 vertical levels

General rainfall pattern across Australia
Annual-average decreases across temperate Australia, with increases over tropical Australia. Widespread decreases in all seasons, but summer increases in tropical Australia, eastern NSW and eastern S.A., and autumn increases in the western two-thirds of Australia.

General temperature pattern across Australia
Increases across all of Australia, smaller increases along the southern coast of Australia.

Link to further information
http://www-pcmdi.llnl.gov/ipcc/model_documentation/ECHAM5_MPI-OM.htm

GFDL-CM2.1 Model

Host organisation
Geophysical Fluid Dynamics Laboratory, NOAA

Country of origin
USA

Atmospheric and ocean model attributes
Atmosphere: horizontal resolution: 2.5° longitude x 2.0° latitude, 24 vertical levels
Ocean: horizontal resolution 1° longitude x 1° latitude with enhanced tropical resolution (1/3° lat/long on equator)

General rainfall pattern across Australia
Annual-average decreases across Australia. Widespread decreases in all seasons, except for summer increases in the northern tropics and southeast, and spring increases in north Qld.

General temperature pattern across Australia
Increases across all of Australia, smaller increases along the southern coast.

Link to further information
http://www-pcmdi.llnl.gov/ipcc/model_documentation/GFDL-cm2.htm

ECHO-G Model

Host organisation
Meteorological Institute of the University of Bonn (Germany) and Institute of KMA (Korea)

Country of origin
Germany and Korea

Atmospheric and ocean model attributes
Atmosphere: 3.75° degrees horizontal resolution, 19 vertical levels
Ocean: approx 2.8° degrees horizontal resolution, 20 vertical levels

General rainfall pattern across Australia
Widespread annual-average rainfall increases, but decreases along the south coast and Tasmania, especially in spring, summer and autumn. Widespread decreases in winter, but increases in central and northern Australia.

General temperature pattern across Australia
Increases greatest in the northwest and smallest in the east.

Link to further information
http://www-pcmdi.llnl.gov/ipcc/model_documentation/ECHO-G.htm

APPENDIX 4 – WORKSHOP REPORT

IMPACTS OF CLIMATE CHANGE ON THE DEVELOPMENT AND MANAGEMENT OF THE NRS

Wednesday 7 February 2007

Background and goals for the project and workshop

CSIRO Sustainable Ecosystems held a 1-day workshop at Gungahlin, Canberra attended by 29 participants from a range of Commonwealth and State governments, research organisations and non-government organisations. A list of attendees and their affiliations and the agenda for the day are included at the end of the report.

The project aims to examine the implications for the National Reserve System (NRS) of the impacts of climate change on biodiversity and other sectors. This includes both management of existing reserves and further development of the reserve system within the context of the bioregional planning framework. The project is an action arising from the National Action Plan for Biodiversity and Climate Change, and is funded by the Australian Greenhouse Office (now the Department of Climate Change) National Climate Change Adaptation Program, the National Reserve System (NRS) program within the Department of the Environment and Water Resources (now the Department of the Environment, Water, Heritage and the Arts), and CSIRO.

The aim of the workshop was to canvass a range of reserve system stakeholders about possible responses to a range of climate change impacts. The findings of the workshop are summarised below and will inform more detailed discussions of possible adaptation responses in the final project report. Workshop participants included representatives from conservation NGOs, private and government agencies responsible for acquiring and managing conservation reserves, and experts in conservation planning.

The project report will help the NRS Task Group (under the NRM Ministerial Council) and NRS Scientific Advisory Sub-Group (SASG) develop any necessary responses to climate change. The main direction currently of the NRS Task Group is to enhance adequacy, develop protection mechanisms, and management effectiveness principles. Key interests of the NRS include:

- how impacts will be distributed across regions,
- what impact on effort or resources might climate change require,
- how to improve coordination of management and integration of science, and
- developing management responses with limited information.

The project will also help develop the foundation concepts and a framework for more rigorously assessing impacts on conservation more broadly.

The National Climate Change Adaptation Program, within the AGO, has been established to commence preparing Australian governments and vulnerable industries, sectors and communities for the unavoidable impacts of climate change. Priority sectors under the program include water resources, coastal regions, biodiversity, agriculture, fisheries and forestry, human health, tourism, settlements, infrastructure and planning, and natural disaster management

Key objectives of the program are to:

- advise Government on policy issues related to climate change impacts and adaptation, including key risks to and opportunities for Australia;
- build capacity to support the development of effective and targeted adaptation strategies;

- engage stakeholders and provide targeted and scale-relevant information and tools to industry sectors and regions; and
- integrate climate change impacts and adaptation considerations into key policies and programs, including into risk management practices across vulnerable sectors.

The project is aimed at building capacity within the NRS, by identifying the risks of climate change to the NRS and identifying where possible, timely and efficient adaptation responses both nationally and at a regional scale, which may assist in minimising the impact of climate change.

The workshop started with introductions and a round-table catch-up on current relevant activities, this was followed by followed by a scene-setting presentation by CSIRO. The presentation outlined a framework for thinking about climate change impacts and adaptation, a summary of various climate change impacts, and a range of other bounding issues to be considered when exploring policy and management responses. Following an open discussion, a series of scenarios of impacts on biodiversity were presented and possible responses discussed for each. A closing discussion covered a range of cross cutting and emerging issues. As well as participating in discussions, participants were encouraged to write ideas on butcher's paper and cards that were collected at the end of the day. The following day, the NRS Scientific Advisory Sub-Group met with the project team and further discussed a range of issues from the workshop.

Below we discuss a range of key issues arising from the workshop, these have been synthesised from discussions throughout the workshop and with SASG. Following that are some edited notes from the workshop and written comments provided by the workshop participants.

Key issues arising from the workshop

While the brief for the project and workshop was to explore the impact of climate change on the management and development of the NRS, discussion of the topic do by necessity involves three much wider topics:

(a) the impacts of climate change on the biodiversity conservation challenge,
(b) the current operation and directions of the reserve system, and
(c) the relationship between reserves and other conservation programs.

Although the project workshop did not aim to cover these wider issues in a comprehensive manner, discussions at the workshop subsequently did venture into these areas and this is expressed in the 13 key issues summarised below.

1. The changing conservation challenge

- There will be **substantial changes in populations and ecosystems**. There will probably be some extinctions, maybe many, although there is contention about how much extinction will occur.
- While climatic changes (per se) with associated changes to biodiversity are a **natural process** and have occurred in the past, there are a series of reasons **society may be concerned** about current changes: they are human induced, unprecedented in their nature, there are important interactions with other human-induced threats, and even "natural" biodiversity change is not necessarily societal neutral.
- The nature and relative risk from different **threats will change**, and change the nature of **trade-offs** between conservation and other uses.
- It is a societal issue to decide what changes are desirable or not, and **what we are trying to conserve**: eg, genetic diversity, specific species, species in general, particular ecosystems, a diversity of ecosystems, patterns of species or ecosystems, ecosystem functioning, particular ecosystem services or values. Climate change will alter the feasibility of different objectives. Different criteria will provide different preferred outcomes.

- Changes in species and ecosystems can be expected to lead to **considerable challenges for conservation programs**. These include mismatches between old guidelines and new objectives or realities; inappropriate planning concepts (eg, stable communities); changing and uncertain objectives; the need for different types of information (about change) and decision making (longer term and with less certainty).
- Current **conservation planning targets may not be suitable** in the future (eg for species management, NRS directions, fire management); reassessment is warranted.
- It will be useful to **explicitly recognise two conservation goals**.
  (1) To facilitate natural adaptation (allow change to happen, remove any institutional or biophysical barriers to change, pro-actively create change); and
  (2) To preserve threatened and valued elements of biodiversity.
  It needs to be recognised these goals will sometimes be mutually contradictory so it will be necessary to choose between them in different management circumstances.
- Given uncertainty in the details of climate and ecological change, **risk management and anticipatory approaches** should be used. There may be difficulties when implementing **precautionary and/or adaptive approaches.**
- Approaches to building the **resilience** of species and ecosystems that maintain ecological and evolutionary processes and functional should be investigated, eg increasing the number and size of areas managed for conservation, reducing threats and increasing landscape-scale connectivity. However it should be noted there will be situations when increasing connectivity increases threat to some species.
- There should be more integration between conservation programs in a **bioregional and landscape framework** (eg, NRS, NRM, species management, environmental flows, threat assessment and management).
- More and better **communication** with the community and managers is needed about possible biodiversity changes and management options.

2. Bioregional and landscape conservation planning

- **Bioregional biodiversity strategies** should be developed linking NRS, off-reserve conservation, sympathetic management, NRM, species management, threat assessment, fire management, pest control, ex situ conservation, translocation, etc in a landscape framework. Such plans should explicitly include all users of the environment including conservation, agriculture, forestry, tourism, urban development, etc, and objectives including production, conservation, carbon sequestration, water management. Regional strategies should seek to achieve a commonality of objectives and targets through a diversity of approaches. These plans should be used to prioritise investment in conservation programs including the development and management of the NRS.
- The different approaches should be **monitored and assessed** for their efficiency and effectiveness.
- Bioregional **management plans should include possible changes** to their descriptions of the system (ecosystems and land uses), the threats, goals of management, management options, and targets, and thus anticipate possible threats and opportunities (eg change into or out of intensive land use).
- **Strategies for landscape connectivity** should be planned at the bioregional level and implemented via the full portfolio of programs. These should also include assessments of the possible risks of connecting threatened and valued populations to sources of new species, and be aware that evolutionary process may favour fragmented islands of speciation.
- Although biodiversity is dynamic in space and time, the locations of **reserves and most other lands managed for conservation are fixed**. These places should be managed for change (not moved), and new conservation areas established to meet changing priorities.

3. Comprehensiveness and Representativeness

- Development of the NRS should be based on a process with a **set of criteria** to be met that guides the benefit for minimising the impact of CC (climate change) and improving the CAR

(Comprehensive, Adequate and Representative) qualities of the NRS. How do the current criteria stack up, what new ones are needed?

- **Comprehensiveness** is based on sampling community-scale diversity. Examples of all ecosystems are not in the National Reserve System and this is a significant gap to be addressed.
- Partnerships and integration with other conservation programs at a bioregional scale, rather reliance on acquisitions alone, may be more efficient and effective especially in regions with little available land. In regions with substantial leasehold or relatively little intensive land use acquisition may be most suitable method of establishing protected areas.
- Many parks are where they are because of accidents of history (eg rugged country); **acquisitions** are now more targeted, however "availability" rather than "threat" is a dominant driver in most cases. Decreases in agricultural productivity in some regions (due to climate change and other drivers) may provide new opportunities for reserve acquisitions or other conservation programs.
- Climate change will see some **ecosystems and communities move or dissolve** completely with novel ones appearing. While this may be a conceptual problem for planning based on the identities of communities or ecosystems, it is likely that the **diversity of communities** included in reserved areas will not change considerably. [There was a comment here that this may not be supported in the literature. i.e. Hannah et al (2005), "The view from the Cape Extinction risk, Protected Areas and Climate Change" *Bioscience* **55.** They argue that communities and ecosystems will become less diverse as they will lose some species and while other desirable species will theoretically experience range increases, they may not actually be able to migrate to reserves due to local geography and landscape barriers i.e. cropping, urban areas etc.] Lack of "climatic" parameters in the IBRA regions may be a strength in this regard. **Representativeness** (sampling variation within communities) may be similarly robust to evolution of communities. Thus, the current approach of sampling the underlying landscape characteristics that support community diversity, at two scales, is a very good foundation for building a resilient protected area network and taking a landscape approach to climate change impacts (this approach could also be useful at monitoring these impacts – if climate change does cause decreases in biodiversity within different systems).
- Various **additional criteria** were suggested for implementing CAR to ensure investments are priorities towards acquisitions that most effectively build **resilience** and **adaptive capacity** for climate change. **Emerging threats** and **changing mix of existing threats** could also be used to prioritise further development of the NRS. Areas with greater **primary productivity** may be important as future evolutionary source areas and refuges; to some extent such areas will be *implicitly* picked up through sampling regional and sub-regional communities. **Rare large tracts of land**, the habitat requirements of **migratory or dispersive species** and **connectivity** of habitat areas could be criteria for prioritising additions to the NRS.

4. Adequacy

- The **changing nature of threats**, increasing **environmental variability**, greater **uncertainty** all suggest that, in general, greater effort may be required to ensure specific species are adequately preserved.
- However "adequacy" in still **poorly defined** from an operational perspective, so there is no current mechanism for assessing what changes in adequacy might be required. Change in species and communities due to climate change make the task of developing an operational framework for adequacy both more difficult conceptually and more urgent.
- General strategies to increase adequacy include increasing the **number of protected populations/areas**, the **size of habitat areas**, **decreasing threats**, and **more "sympathetic management"** in adjacent areas. In some situations **increasing connectivity** will increase adequacy, but it must also be remembered that **decreasing connectivity** (to predators and competitors) is a primary tactic for conserving vulnerable species.
- Reserved areas will need to be adequate for **existing species** and **adequate for future species** that might have different requirements for area, resources or mix of habitats.
- If climate change sees **existing communities dissipate and new ones form**, then it is conceptually unclear what "adequate to conserve communities" might mean. **New criteria** might be needed to assess what is adequate at the community or ecosystem scale; something based on

ecological processes (at appropriate scales) or maintaining **functional diversity** might be appropriate. Including **high productivity** areas and **connectivity** between similar and different communities may also increase adequacy.

5. Management

- Climate change probably poses a greater **immediate challenge for reserve management** than for the future development of the reserve system. Individual reserves need to manage for a **changing biodiversity.** Some of the changes may be judged to be negative ("less" biodiversity, expansion of "undesirable" species), neutral or positive.
- Their specific management **goals need to be redefined**: facilitating change, or preserving vulnerable and valuable entities.
- Park managers are confronted with many inconsistencies between (old, static) guidelines and (new, dynamic) realities.
- A new management framework isn't needed but the existing framework needs to be more adaptive to the impacts of climate change.
- Parks will face changing and new threats, and well-developed current management proscriptions may cease to be effective. In managers will need **new guidelines, new types of information and new management tools**.
- Managers are also faced with increased **risks to visitors** (eg changed fire regimes) and changed visitor management (eg water supply).

6. Changing threats

- Climate change will significantly **alter the nature and mix of threats** nationally, in many regions and for individual reserves. There are also strong **interactions between climate change impacts and other threats**. For example: habitat fragmentation combined with shifting climatic envelopes, reduced rainfall/increased evaporation combined with human diversion of water, reduced habitat combined with increased predation increases the level and impact of threat.
- As discussed, changing threats has various consequences for **reserve management**, **prioritisation of development of NRS**, and **prioritisation of conservation investment**.
- **Reducing threats** may be the best option for increasing the resilience of species under climate change.
- Many threats will change, **four big threats** are:
  - New species.
  - Altered water systems
  - Land use change:
  - Altered fire regimes, and their management
- Drought, storms, flooding, fire and other **disturbance regimes** (intensity, frequency, seasonality) are likely to change, with impacts on species and ecosystem composition, structure and function.
- Australian conservation planning has been **poor at doing threat assessment** and factoring threats into planning of conservation investment. It is not used as a driver when it is clearly important (it is inefficient to invest in conserving non-threatened systems), however this is partly because threat is often correlated with the cost of conserving.
- In some situations, better knowledge of threats, especially how they may change in the future, could be used. For example in particularly under developed/represented regions, or when land prices are not correlated with changing threats.

7. New species

- Climate change will lead to **changes in the abundance and distribution** of many species; this means some previously absent species are likely to arrive in reserves and regions, and previously sparse or low-density species my increase in their abundance.
- Some "new" species will be **native species** spreading from their current distributions, others may be **exotics spreading** from naturalised populations, "escaping" from agriculture or gardens, or

dispersing from elsewhere. In particular many **weeds and pests** are likely to expand their distributions and new ones will emerge.

- New species could have considerably **variable ecological impacts** if they establish. They may establish in low density, or become a dominant; they may out-compete present species, become valuable food or habitat, or be significant pests or predators; they may have relatively little impact at the ecosystem level or may transform composition, structure or function (including fire regimes) in some way.
- Each of these impacts could be judged as being **desirable or undesirable** depending on the circumstances and the choice of criteria. In general there is very low predictability about which new species will establish *and* what impacts they may have. **Phylogenetic relatedness** and **functional types** may provide some predictive ability but they will be weak for most species.
- **What are the conservation implications**? At one end of the spectrum the arrival of a **new native species will probably be OK** (being natural adaptation of that species, as long as it does not have an overwhelming negative impact on present species that do not have populations elsewhere). It may be positively desirable for some new species to establish, either for their own conservation or to provide habitat for other species; it may be desirable to actively facilitate their establishment (eg **translocation**). However, experience suggests translocation is intensive, has low success and frequently has unforseen negative consequences, and there will almost always be a high level of uncertainty about how necessary it is (i.e. what are the risks of not doing it?).
- At the other end of the spectrum, arrival of **rapidly expanding exotic or native species might frequently be judged as undesirable** especially if they have a transforming impact, but this will not always b the case.
- There are currently **no conceptual or operational frameworks** (that we are aware of) for effectively analysing the consequences, desirability, and suitable management responses to new species arrivals. **Australia needs to have a major "national conversation",** over decades, about this phenomenon, (much in the same way we are having a national conversation about fire management).
- In the mean time, **managers need guidance** and in some cases improved legislation or revised targets to assist them with this already occurring phenomenon. And further **research** is required about the predictability and management of potentially transforming species, and species movement, establishment and new ecological interactions more generally; and this should entail considerable monitoring of native, agricultural and urban ecosystems.
- A strategy might be to develop regional monitoring programs and consultation networks to try to identify emerging species or species changing their range.

8. Fire

- Climate change will alter many of the factors that affect fire regimes: production and curing of litter, dryness, fire weather, ignition (lightening). Changed regimes will affect the composition, structure and function of ecosystems, which will feedback to affect fire regimes. Nutrient and water balances will also be affected.
- There will also be impacts on urban areas and infrastructure, and public safety.
- Fire management strategies and protocols that have evolved in regions to historic fire regimes may become unsuitable. There could also be considerable ecological impact from un-strategic fire management. In particular, attempting to keep fires to historic frequencies or intensities through fuel reduction; or, more frequent "reactive" or "emergency" fire management using mechanical fire breaks that are poorly planned, located and constructed that are themselves likely to introduce weeds right at ideal establishment times, and may not be as effective as better planned fire breaks.
- Biodiversity managers and the community need to **recognise and accept changing fire regimes**.

9. Land use change

- Climate change, including changes in CO_2, temperature and the seasonality amount and variation in rainfall, are likely to lead to changes in **agricultural productivity** (including grazing on rough and improved pastures, broadacre cropping, semi-intensive cropping, and horticulture) which will almost certainly lead to **significant land use changes**. There will be productivity increases in some areas (leading to expansions in agriculture) and reductions in others (leading to contractions), and changes in relative productivity (leading to switches between types of production). Climate is of course but one of many drivers of productivity. All of these changes in landuse will have impacts on biodiversity.

- There will **opportunities** to expand the conservation estate or establish sympathetic management in some regions, and increased **threats** from intensification in others.
- The greatest threats could arise from **conversions of grazing lands to cropping**; this will happen in areas that are currently to wet for cropping and are likely to dry in southern Australia, and areas that are currently too dry to crop that may get wetter on inner margins of the wheat belt and Northern Australia.
- Reductions in water availability for irrigation in southern Australia may also see investment in **development of irrigation in the north**, with consequent impacts on rivers, wetlands and estuaries, direct impacts on cropped areas, and introductions of new weeds and pests.
- Further expansion of coastal Australia is clearly a pressure on biodiversity; rising sea levels and changed cyclone regimes will confound this pressure in some areas.
- **Biomass production** for the energy industry could also be either a considerable opportunity or threat for biodiversity conservation.

10. Water resources

- Climate change will alter the **dynamics of surface and ground water** and plant and animal **requirements** for water. In many places both changes to hydrological cycle and the impacts of those changes will be **amplified by human extraction** of surface and ground water.
- These changes will affect **aquatic species** and many other **species dependent on rivers** and wetlands for food, water or habitat.
- Locations with good surface waters, and accessible groundwater, are frequently **drought refuges** and **staging posts** for mobile native species. These may become **more important** if climate becomes more variable, and they also may be **more vulnerable** to changes in rainfall and hydrological cycle.
- More frequent or permanent **drying of wetlands** may lead to expansion of grazing, pasture improvement or cropping into areas of locally productive and unique habitat.
- Responding to and managing the impacts of changed water regimes are made especially complicated by the dynamics of water, and **societal dimension** of water including multiple trade-offs with many different human uses, rapidly increasing human use, historic over allocation, uncertainty about ecological impacts, high level of social and political contention and rapidly changing institutional arrangement.

11.Single species vs. strategic management

- Most conservation in Australia occurs through **strategic management** and investment, eg NRS, addressing threats (eg, land clearing), although **single species management** (eg, threatened species processes and pest/weed control). They are both effective and necessary. However, there is often a **trade-off** between them in terms of investment, and they may clash in terms of conservation objectives. While sometimes derided by conservation managers concerned with the efficiency of conservation investment (spp/$), single species are always likely to have a high societal priority.
- Conservation responses to climate change may exacerbate some of the **tensions between strategic and single species management**. For example, there may be increased demands for investment in conserving new/more habitat areas to increase resilience, and increased demands to intensively manage individual species that are becoming increasingly vulnerable. While more resources in total may be warranted, the **increased tension should be anticipated and managed**, including through revision of legislation, guidelines and targets where necessary.
- This will be particularly important given that significant changes in population abundance and distributions are to be expected. One possibility would be for scarce conservation resources, from

the national through to the individual park level, to be **increasingly diverted to managing single species** whose populations have been observed to be declining (or expanding), many of which may not actually pose a threat or may be effectively unmanageable. In addition **ex situ** and **translocations** may become the only possible options for conserving some species. A bioregional approach to biodiversity management, integrating all conservation and NRM programs, and incorporating likely change would reduce the risk of such outcomes, and increase the likelihood of finding synergies between single species and strategic conservation goals.

- Single species management, especially given the changed dynamics due to climate change, will require an amount and accuracy of **information that will never be available** for the vast majority of species. Attempting to generate this information (often with “false precision”) will also divert resources from generating information required for more strategic management. This is particularly the case for species translocations, which in general are expensive, and risky in terms of long-term success and avoiding unwanted outcomes.

12. Information needs

- Information is **currently a constraint** to management of some reserves (eg, don’t know what species are present) and conservation continental scale (spatial resolution of habitat condition and threat assessments too coarse to be useful).
- Changes in species and ecosystems, threats, and conservation objectives as a result of climate change all **require new information** be used for conservation planning and management.
- The types of information that might be useful include information about:
    - species identity, presence, abundance, distribution, ecology, functional responses, including thresholds,
    - population and ecosystem dynamics in response to climatic and environmental change and threats,
    - current and future changes in climate (including extreme events), environmental conditions and threats,
    - ecosystem and evolutionary processes,
    - levels of genetic, functional and habitat diversity, and
    - ecosystem services provided by reserves and other conservation areas.
- In addition information needs to be
    - at the right **scale** (eg “average” climate information not particularly useful)
    - **available** to managers and planners,
    - in a useful **format**
    - and used by managers and planners with the **necessary skills**,
- Managers will need to get better at **working without information** or with partial or surrogate information. This will require some risk management.
- Australia currently has too **few taxonomists** to provide information about species and phylogenetic relationships that might be useful for predicting species ecological responses.
- It may be useful to explore **predictive modelling** of surrogates and processes including **functional types, architectural species, ecological responses, evolutionary processes** and **ecological resources including productivity**, as an alternative to information about patterns of single species.
- Currently it is quite **unclear what types of information** about environmental and ecological changes, and at what scales, **will provide the best marginal benefit** to conservation managers planning for climate change.
- Need more surveys of what is currently there, and **monitoring of how species and ecosystems change**. Such monitoring should be linked to future policy and management decisions that could be improved with the additional information. Similarly management, using experimental design principles, can be used to test ecological understanding. This required partnerships between researchers, policy and management, for effective design, resourcing, implementation, analysis and adoption.
- Information should be targeted toward **the public, planners, on-ground managers, researchers and politicians**, addressing likely changes, their implications, what are realistic expectations,

possible management options and decisions that need to be made. Information (and we) also needs to recognise that people change by small increments and progress will be gradual.

13. Future priorities

There was reasonable level of agreement emerging about a series of priorities for the NRS and conservation.

- **Complete** the comprehensive, adequate and representative reserve system using the current **IBRA framework**;
- Improve resilience of the system with **increased number and size** of reserves, more **off-reserve conservation**, targeting of areas of **high productivity**, and **better management** of reserves and private conservation lands.
- Manage **biodiversity change** with static reserves.
- Establish **landscape connectivity** especially using off reserve conservation.
- Better **targeting, monitoring and evaluation of conservation on private land** to improve management and outcomes (eg, beyond tree planting).
- Better **threat assessments**, incorporation of changing threats into prioritisation, and targeted anticipatory **threat management**.
- Ex situ and gene banking as a **last resort**.

These actions should be supported by

- Reassessments of biodiversity conservation objectives and targets given the realities of climate change.
- Bioregional biodiversity strategies, with tailored mix of responses in NRS, NRM, etc, and anticipation of changes.
- Better presented and new information about climate change impacts
- Strategies to achieve a balance between strategic and single species investments

General conclusions

- Expectations need changing; many people find it hard to grasp magnitude of changes and impact they will have.
- Comprehensiveness and representativeness - current processes are robust to climate change and will help built resilience.
- Adequacy needs to include additional threats and uncertainty – build into the evolving adequacy framework.
- A range of new or increased threats will emerge, including:
    - New species – need a framework.
    - Changes fire regimes – need to anticipate and manage strategically not reactively.
    - Landuse change, includes both opportunity and threat (including conversion of grazing lands to cropping; wetlands; north Australia); much to be gained by anticipatory actions.
    - Surface and ground water changes: societal dimension makes this hard.
- Lots of new information required.

Actions arising from the workshop and where to next

1. Send draft of this summary and notes to DEW.
2. Circulate document to workshop attendees:
    a. Seek comments,
    b. Correct errors.
3. Consult additional experts and stakeholders.
4. Incorporate comments from all into final report.

Notes taken during the day (courtesy of Rachael Dempsey, DEW, edited by CSIRO)

<u>AGO's involvement</u>

- AGO works collaboratively with NRS.
- Evidence of cc is now recognized, resulting in greater focus within AGO. The RATE of cc is faster than in previously history and therefore the challenge is to minimize loss resulting from the inability of species to adapt.
- Cc impacts are uneven making responses difficult to determine.
- Need to address adaptation to impacts planning early to enable resilience and coping with adaptation
- Work: 2004 efforts started. Across sectors and regions (in addition to bd). Marine bd, water, world heritage properties. In collaboration with other agencies and CSIRO.
    - NRM ministerial council announces (Dec 2006) new program (2.7m). 11 actions: bd vuln assessment, coastal vuln, and ecological water assessment
- National cc adaptation program (Feb 2006). Key actions: understanding adaptation and vuln and reducing vuln.

<u>Round Table – update on cc and bd news/activities around the country</u>

- Environmental Futures Network
    - phylogenetic patterns
- Carbon toolbox (??)
- Disturbance regimes
- CO_2 and vegetation productivity at a continental scale
- Forestation and relationship to water storage (implications of fire)
- Public safety (fire, heat) a management issue
- Partnerships in large landscape conservation projects
- Biodiversity atlas of Australia – public dissemination of biodiversity information
- Recent book: Wildlife – fire – climate – (B Mackey CSIRO 2002)
- Other countries
- Property scale response to cc impacts and making this work at a regional scale
- Core protected areas versus connectivity and designing conservation planning
- State approach to biodiversity conservation and adaptation to cc
- Islands to networks, diversity of govt's, conservation in the context of societal benefits and livelihoods (social justice), moving the IUCN agenda in a non-political manner
- On-ground conservation tools, revolving funds, covenants and moving from islands to networks (PAPL Tas) → bioregion planning for adding to the network and landscape resilience - - what range of climate information is available??!
- Biodiversity directions (QLD): arid lands, large scale mining – biodiversity offsets, many opportunities for a new approach to biodiversity conservation, new lease conditions, retirement of marginal land, cessation of broad scale tree clearing, revamp the reserve network approach, bioregional planning including new considerations and on and off reserve lands.
- Data management at an intra-governmental level
- Botanic gardens house significant proportion of Australia's flora, to some extent by managing suitable climates.

<u>Presentations –see ppt slides</u>

Framework for identifying impacts:

- Cascade of impacts from Environmental through biological and ecological to societal
- Useful for thinking about various observations, predictions and likely impacts:
    - Changes to timing
    - Changes to distribution and abundance
    - Feedbacks (nasties: compounding effect of species on others)
    - Broader social goals and expectations (eg re: mitigation)

- Intersect the cascade with a five step plan for thinking through possible impacts, information requirements, implications of impacts and possible policy and management responses.
- Workshop will like to focus on answering step five *"What can I do about various possible impacts?"*

Summary of **"cascade of impacts"** of cc on bd
- (env scale) Drivers – interacting effects – variability
- (indiv biology) Drivers – physiology, timing, behaviour – energy, phenology
- (indiv ecol) Interaction env – indiv: dynamics of relationships to env and others, dyn of communities, change in ranges and vectors
- (spp pop) abundance and distribution; water-energy balance; dispersal and migration and fragmentation, vuln & extinction, loss of core environment
- (ecosystem) different responses by different systems, changes, shifts in boundaries, changes in composition
- (soc values) use and non-use values, relationship with (look, feel, sound of an ecosystem

Scenarios of possible types of impacts on biodiversity to help us think about what might happen, the implications of that and how we could respond.
- Local changes in relative abundance and vegetation structure
- New species arrive in a region
- Declining populations – do some matter more?
- Localized losses of spp
- Change in the nature of other threats to biodiversity – may alter priorities
- Global losses of species
- Ecological impoverishment – loss of conservation values, diminished ecosystem services

Conservation objectives may change – Can we construct a hierarchy of goals? (bottom most important); preserve:
- relative abundance
- local spp populations
- genetic variation
- beta diversity (prevent a homogenisation of biodiversity)
- ecosystem types
- global populations (prevent extinction)
- some form of ecological function

Realities (social, political and biological)
- Parks cannot move
- NRS additions do not stepwise improve the condition of biodiversity, they prevent decline
  - (This was contested)
- Relationships and priorities of those we partner with (stopping tree clearing)
- Expectations for management (management of "particular" spp)
- Building large connective areas is tough – what is the role of NRS (?!)
- (Issues) Insufficient resources, winners and losers (some spp loss), low predicability, vulnerability – how can we use what we know to help planning?, tension between multiple goals (spp, ecosystem, and landscape management; what about overlapping responsibilities of state agencies, and across jurisdictions and levels); (re: range shift/ optimal conservation, optimal habitat, optimal investment; refuges in a climate of change (new opportunities; those that are 'doomed', human managed refuges)

Possible reserve/conservation **management changes** to consider
- Levels of management (local priorities)
- Priorities for NRS

- Priorities for conservation as a whole
- Facilitating change and/or maintaining spp/ natural values; may contradict each other

Open discussion

Implications of CC for goals of conservation

- Balancing act between multiple and divergent priorities, “they all matter”; multiple criteria problem. [But is it if they are a hierarchy??]
- Data needs to be collected at the appropriate scale to fill in gaps as well as address urgent issues
- Legislation requirements can be perverse or an impediment (X’s requirement to manage at a spp level may not jive with someone else’s)
- “Scientific” compared to societal and other interests may result in ‘trade-offs’ for biodiversity conservation; setting priorities, defining the management framework and defining goals (a $70 b tourist industry depends on protected areas, too, but different attributes of them)
    - how can a “science-based management framework for building the NRS” with a focus on spp level conservation, for example, avoid missing key issues such as genetic loss, bioregion protection, or socially significant issues that are of greater interest to different decision makers and stakeholders
    - how can information be presented to these decision makers (with seemingly other priorities), relate it to their interests
    - how do we prevent the leap to solutions without carefully thinking about the complexity of the situation
- Partnerships are about social change and understanding climate change
- Change management process with static entities (protected areas that cannot move, may not be in the “right place” in the future) →managing buffers and linkages (we are trying to get better accord with NRM re: areas adjoining NRS protected areas)
- Protected areas are not merely static, they involve dynamic and long-term community involvement (adequacy, values in the landscape, why are they valued, how the management plan is addressing this)
- We are not yet adequately evaluating the successes of different approaches to biodiversity conservation; eg long-term versus 20 Mha of “soft” [off-reserve/incentive-based] conservation approaches; let alone assessing their effectiveness under climate change.

- Need to think about
    - Which values are likely to be affected by cc
    - Why and how
    - Which changing values, how do we determine these
    - Which priority actions, how do we determine these

- Need to recognise what we have described are natural processes – we should be alarmed if they did not happen!
    - “Don’t see a priori that there will be significant loss of spp as claimed by some.”
- What makes our current circumstances and this cc special?!
- Interactions with other (and current) threats, amplification of impacts, human interruptions to natural adaptation processes.
- Humans have caused the climate change so are responsible for any losses, and “Vague belief we can do something about it”

- What is in our toolbox of responses? Is the climate change toolbox empty?
    - NRS and others existing programs as platform for biodiversity conservation
    - Is this platform robust in light of cc, or do we need another planning framework
    - There are opportunities to elevate land management into other activities and decisions

Discussion: Implications of and adaptation responses to impact scenarios

Scenario #1 Changes in relative abundance, vegetation structure, ecosystem type

Disappearance/change is not all bad: does a healthy natural ecosystem and its adaptation to cc create a significant challenge to CAR?

- Conserving an ecosystem type versus
- Adaptability

Are the CAR targets a hindrance?

- Adequacy addresses this issue of natural processes
- Depends on what we are trying to achieve: facilitate adaptation versus mitigate impacts

Are there economic tools emerging that might help buffer protected areas and establish connectivity.
[the discussion before lunch really did not get beyond this]

When it matters

When the broader system is not robust (underlying ecological processes)

When a sub-system is not replaceable (spp, interactions, functions) in some other part of a broader system is less important

What we can do

Indicators that it's happening

Appreciation – Natural value also includes the evolutionary and genetic diversity components – not just what exists there presently.

Aside: Potential outcomes/recommendations from the workshop for managing the NRS esp CAR.

Given what we know, what do people feel is needed?

1. Do nothing different
2. Do more
3. Do a bit different
4. Do totally differently

We need to distinguish between 'development' and 'management' of NRS. Development is an issue of affordability (financial and political constraints). We can do more for management more easily.

Re: 2.
[most nominated this]
We do many things well, but need more buy in and investment from the politicians and the public

Re: 3.

- Changing ecosystems is potentially a big problem for planning processes based on ecosystem identities.
    - Brings area or % based targets into question
    - Are there alternatives, would variable targets (depending on threat) be better
    - JANIS was a sliding scale, NRS not area based (80% *of communities* not area)
- What are we actually trying to preserve with out targets
    - [Should we interpret the target as "x% of identifiable communities from a list", or "x% of the community level diversity that is out there"?]
    - CAR is actually pretty well designed for that job, focus on finishing it; and/then work on other threats.
- Productivity a key missing dimension to conservation planning
    - Quality vs area for comprehensiveness

- o Important for speciation, survival, “source areas”
  - o Covered implicitly by sub-regional variability = representativeness criterion
  - o Could be a new explicit criterion
  - o High prod areas tend to be under free-hold tenure, or refuges and this has implications for the NRS
  - o high productivity areas are more complex, resilient, adaptable, long-term viable

- Adequacy very poorly dealt with, what does it mean in relation to climate change?
  - o Ecological processes
  - o Evolutionary processes
  - o Stretches our current predictive capabilities, need new criteria
    - Spp level poor
    - Functional type level more robust
  - o Functional diversity/redundancy,
  - o responses of functional types to (multiple) stresses
  - o evolutionary potential

- public perception that we are not managing well (due to misunderstanding of the information and the reality that some spp will go extinct - no mater what)
- We need to sort out on-going threats and climate change threats and develop the NRS to reflect this. Is cc – our response to it – helpful to on-going objectives?

Re: 4.
Need to do something totally different as it relates to managing the interaction of threatening process

- Three key priorities for conservation (not mutually exclusive):
  - o Complete NRS with IBRA
  - o Add connectivity
  - o Do a much better job at assessing and dealing with threats, including expanding the tool box [incentives etc]

Scenario 2: new spp arriving

- What spp shifts are good/ bad? Cc will influence which weeds prevail and which (introduced spp) will become a serious weed. Migration and dispersal are natural conditions for adaptation.
- Transformer spp have what impact on biodiversity, fire regimes, health… and can we focus on what outcomes we wish to achieve.
- Public perspectives that the protected areas are the “breeding grounds” for things that escape, things they do not like.
- Pest spp a major issue
  - o Going to happen
  - o May examples of major changes due to a spp or functional type expanding / being favoured by changed environment
  - o Will be a transforming process
  - o Where will the weeds come from? From parks, into parks??
  - o
- A whole new suit of spp on the move.
  - o The ability to tell others what is happening requires taxonomic surveys! And taxonomists will be nonexistent in ten years!!
  - o Use phylogenetic relationships to predict invasiveness
  - o Monitoring needed
  - o ½ Aust birds can travel a long way [and carry seeds/plant material]

- Most changes will be subtle, eg changes in abundance
    - There will be lots of change, that is prob OK
- So, is it a new or invasive spp? Managers need guidance.
- How do we detect transformation (and their management) processes that are acceptable acknowledging that any one will not be foolproof?
- We need to get better at seeing our "patch" (protected areas) within the broader landscape and it planning.
- How do we establish indicators under the influence of a changing climate?
- We are going to have to accept extinction in our extreme, special environments.
- Barriers to adaptation, barriers to connectivity/ permeability, barriers to migration and dispersal.
- What is connectivity – 7 ecological processes and phenomena that need to be connected – it is not a mere hallway between islands. (affects evolution, extinctions, migrations, …)
    - The evolutionary process may favour fragmented islands of speciation.
    - How does connectivity relate to the mission of the NRS to conserve large spp?[?]
    - Staging points that bridge distant points.

Scenario 3: declining species – pass

Scenario 4: local loss of spp (but not extinction)

- It is never one factor that is involved. It won't be just cc to blame.
- The public will never accept the loss of some spp without a fight – regardless of its expense and irrevocable outcome – a "reality".
    - At what point in time do we start/stop ex-situ actions?
    - Expect (in policy terms) more ex situ conservation actions in the future.
    - But translocations have very poor record, maybe 90% fail, we only hear about the successes.

- Corridors, translocation, ex situ actions, Noah's Ark (ANBG)… fallback options??

- Must not let recognising some loss will happen become an excuse not to act in ways that might prevent cc or loss

- Are there spp that face one threat – CC?
    - Qld endemic vertebrates are possible examples, corral, some alpine plant

- Tool: establishing more reserves (before we seriously talk about corridors)
    - [Prevent further losses before we invest stacks in processes, rehabilitation?]

- Changing climatic envelopes will not kill spp directly, but limiting habitat conditions/ resources will.

Scenario 5: changes in other threats

- CC intensifies effects/ threats due to land cover changes/ land use, water flows and storages,
    - North Australia and Rangelands two areas vulnerable to land use X cc impacts
    - Also grazing areas that might transfer to cropping: drying high-rainfall grazing areas and wetting semi-arid,

- NRS is one part of the approach to adaptation to cc. Given that it will only occupy 10-15% of the land, which portion is this and what are the other bits and how do they all integrate?
    - What are the issues of conflict?
        - Drought relief is keeping land stocked.
        - Different mix of spp for grazing pastures currently being pushed will exacerbate the situation

- ‘Stewardship’ will make it tougher by artificially inflating (property) prices. Priorities for expenditures under this program… may bring about culture change in views about sustainable development – we have to be paid to do it, it lowers performance criteria
- Untargeted (unscientifically-based) protected areas on private land projects (as in NSW) and inadequate resourcing and monitoring – see Costa Rica as good example how it works, but does not address our institutional failure; what are good AU examples to well targeted projects? Have they produced much for biodiversity?
- Could have used stewardship approach very successfully to meet targets better in RFA if it had been available.
- Qld doing lots on offsets, regrowth, replacement+
- Can we pick up on emerging threats such that grazing to cropping land shifts?
    - Before they happen, after/during will be too late
- Managing threat is very close to seizing opportunities perceived to be under low threat. (large intact areas can fall into this category)

What approach do we take regarding areas dependent on groundwater.

- Grazing is a compounding disastrous combination

Closing discussion - High-level issues

- What are we conserving?
- Will changing threats (due to CC) change reserve priorities?
    - In theory three key criteria: uniqueness, vulnerability (threats) and availability
    - But, in reality availability (and price) are major drivers of development of NRS rather than threat.
    - Typically most threatened are most expensive.
    - But will this change with cc, either price changing as agric prod changes (retirement, stewardship), or new threats emerging in under developed areas??
    - Environmental info, relevant to threats, is typically too coarse to be useful for priority setting for development.
    - Overall we have not done threat assessment well in Australia, nor incorporated them well into planning - MUST DO BETTER.

- Approaches to prioritisation: based on precaution (threats, vulnerability reduction), opportunism, Indigenous lands, benefits, uniqueness, feasibility
    - Precaution can be ambiguous for CC: is it more precautionary to act or not act if we don’t know the relative up and down side risks of each?

- Changing expectations
- Fresh water ecosystems: productive, important, vulnerable, under the hungry eye – the rivers
- Increased fire means you need a larger area to support a given number of species due to varying fire histories and requirements.
- In a trade-off system (with social benefits in the mix) our selection will become more complicated

Nasty synergies and interactions

Individual spp or reserve system

Current NRS planning tools

Operational impacts of CAR

- Limited resources may alter/ skew priorities (productive = resilience??)
- Refuge from climate change is not necessarily a (current) refuge from other threats

- Comprehensiveness is well captured; Importance of partnerships in building comprehensiveness
- Adequacy is hard to think with respect to the survival of a community.

Planning for uncertainty

Climate & environmental information format, interpretation, translation for decision making and planning

Toolbox

Thoughts provided on cards

We asked all participants to spend 7 minutes writing on cards what they thought were some of the big issues coming out of the meeting. This was done to capture people's perspectives, but also ensure some things were not missed in the discussions.

The views represented below are those of individual workshop participants (names are deleted)

Participant 1

- Minimising other threats, maximising health of reserve system should be high priority
- Expand reserve system urgently – incorporate refuges/productivity (source landscapes) urgently as part of response to CC
- Don't use CC as an excuse not to spend money dealing with current known problems for BD (weeds/ferals/fire/etc).
- Develop NRS in landscape context with whole of landscape "conservation plans" which improve NRM strategies
  - Promote "conservation" landscapes with core reserves supportive management outside reserves
  - Ensure "connectivity" for key ecological processes.

Participant 2

- I believe IBRA is well established as a basic tool but often "layers" must be added particularly the concept of the most highly productive (highest photosynthesis) sub regions of IBRA regions.
- There are arguments for layering non-representative areas but also the large relatively intact systems of Northern Australia should have priority as a globally important opportunity.
- What are we trying to conserve? – ecosystems & ecosystem values and benefits.
- How will priorities change?
  - Greater triage, invest less in non-viable small reserves??
  - Greater emphasis on varied forms of governance in addition to public Protected Areas – Private PAs, indigenous PAs, covenants, land stewardship etc). All $$ should be directed at targeted priority regions, not shotgun politically derived pork barrel.
- CAR needs as extra "R" for "Resilience" – we should if we have to chose target the areas with the greatest capacity to assist species to survive
- Planning for uncertainty – in detail difficult but obviously the more areas conserved or well managed creates a degree of build in insurance against major events such as catastrophe storms/fire/pathogen attack.

Participant 3

- CC is only 1 part of a raft of threatening processes. The response to all threats is a robust reserve system, good off reserve conservation and effective management.
- The key to biodiversity conservation is ecological function at a scale relevant to the species.

- Protecting sufficient habitat for resilience of niches is critical – adding more lands to reserves is urgent & important. In addition, landscapes must contain connections in order for species to move and migrate → ecosystem evolution. So "soft" conservation in landscape also important.

Participant 4
- Climate change, alone, isn't seen as requiring highly specific responses, rather it forms one of a range of issues influencing future of NRS.
- Species level issues important, but not paramount.

Participant 5
- Almost total lack of knowledge on which to make decisions:
    - Baseline BD (eg species conserved/available) in each area
    - Biological/ecological processes
    - Taxonomy
    - CC predictions for each protected area
    - Information at population level
        - CC will act on populations/individuals, not species
        - Population genetic constraints to breeding/recruitment
- Access to authoritative/defensible data (occurrence, distribution, climate, ecological, legislative, social, political, etc)
- Role of existing ex-situ conservation, and contribution to reintroductions translocation and so on.
- Focus on species for decision making, yet hardly any species info available.

Participant 6
- BD needs a higher profile/priority in NRM/NHT.
- NRS needs to be integrated with NRM, Stewardship, landscape recovery to maximise the contribution of the NRS to minimising the impact of CC
- Development of the NRS should be based on a process with a set of criteria to be met that guides the benefit for minimising the impact of CC and improving the CAR qualities of the NRS.
- An ecosystem and landscape approach is the best way of ensuring the conservation of Australia's native BD is assisted by the NRS and minimising the impact of CC on BD.
- Adaptation is probably the best strategy to address CC while removing threatening processes.
- For the best value give priority to more productive/resilient parts of the landscape – more chance of success, larger slice of BD protected.
- The CAR principles work in the face of CC
- Modify the bioregional framework to better account for possible impact of CC.

Participant 7
- There seems to be consensus that the concept of a robust reserve system coupled with targeted conservation across the rest of the landscape are critical and that they are interdependent.
- With this new threat emerging and the feel that:
    - The NRS is less than ½ complete and conservation on private land is not always focussed
    - It's critical that Fed/State governments significantly increase funding for building/managing the NRS, develop system processes that allow better targeting of conservation on private land and significantly increase funding for effective conservation on private land (not tree planting at expense of more immediate strategies)
- Better communication between all players on/off NRS will lead to more targeted approaches.
- CAR – the NRS deals best with C & R and in the face of CC we need to speed up the achievement of these targets. A – the reserve system will never be "Adequate" because Adequacy relies on management around (outside) the reserve. To achieve "Adequacy" this is where "off-park" initiatives are so important.

Participant 8
- Discerning on-ground changes – what is measurable?, keeping tabs on trends vs extremes.

- Assemble a hierarchy of responses:
  - Re-calibrate and/or reaffirm objectives
  - Explore mechanisms for building resilience
  - Impact minimalisation strategies
  - Enhanced bioregional(ality?)
  - Fail safe options – eg genetic fingerprinting
- Develop communication strategies to address community expectations.

Participant 9

- Need to consider CC as it interacts with current disturbance regimes and how these may or may not change as a result. Eg fire, drought. Need to consider the regime as: frequency, intensity & seasonality & the response as composition, structure & function.
- Need baseline data on response variables both with & without CC.
- Systems level view needed at one level (coarse filter) plus specific species at risk responses at another (fine filter).

Participant 10

- Impacts on unknown BD
- Loss of evolutionary potential

Participant 11

- Rather than manage for spp, planning to manage for healthy landscapes – maintain ecological function and ecological processes. Promote evolutionary potential and functioning diversity.
- Predict current environmental limits and future environmental limits.
- Identify regions at risk or resilient. Relate functional types to particular environmental types. Predict ability of functional types to adapt to new environmental regimes.
- Model changes in distribution/abundance of architectural species. Habitat architecture/substrate
- Model changes in resource availability, water, temp, nutrients, light, ecophysiological predictors, vegetation productivity
- Parks as central to connected landscape – biological preserves within a functioning mosaic of landuse & habitat within intact ecological processes and evolutionary potential.
- Frequency & duration of linking physiological [not able to interpret word]

Participant 12

- Linkages of CC to sea level rise & subsequent conversion of a terrestrial park to a “marine park”.
- Merit of purchasing buffer lands surrounding parks (that might not currently contain vegetation) for vegetation retreat or boundary realignments.
- If National Park habitats (veg formations) change is the new boundary still adequate to support the new species that may have moved to the area?
- Future NRS funding will it be driven towards lands that take CC into consideration?

Participant 13

- Need to investigate measures of adequacy and how the reserve system contributes to the “ecosystem services” of the landscape – this is already being done by the NRS SAG but as well as selling the “C” and the “R” parts of the NRS (to government/funding bodies), more effort could be put into educating both the public & politicians about the ecosystem services provided by the NRS. Eg, reserves may be where they are because they are not overly productive, but they often form an integral part of catchments.
- We do need to do more (acquisitions/education) and the CAR framework needs to be kept after all, it can be modified to take into account changes in ecosystem/vegetation types, etc.

Participant 14

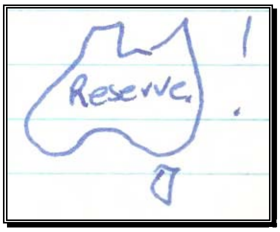
- Need to greatly expand effort in building Australia’s comprehensive reserve system as 1st priority with our understanding of threat. CC adds to the urgency.

- Need to adopt a more targeted, complimentary off-reserve protected area system that is managed and monitored.
- Need to develop strategic BD strategies for each of Australia's 85 bioregions with a tailored mix of conservation responses that includes developing the NRS.
- Need to understand better the interaction of CC with other threatening processes to guide future management of PAs.
- Need further research into impact of CC and prioritisation of key habitats/species in terms of threat and refuges.

Participant 15
- Need to seriously consider and emphasise in report future BD/CC adaptation and future agricultural/economic adaptation – and how conflicting interest may clash. I.e. Very important to consider 1) proposals to develop "the north", 2) future over extraction of ecological water. And how these will affect future directions of NRS.
- On a related issue – abandonment of non-viable farming/grazing land under CC which could represent a) an opportunity to NRS – land purchase refuges for indigenous species, b) a possible threat – how manage great tracts of land that could harbour weeds represent a fire threat etc etc to NRS priorities.
- Consider relationships between a) adaptation – development of NRS, b) CC mitigation – carbon sinks – what role if any the NRS/private stewardship agreements could play as carbon offsets – taking on board the point about Russian research indicating the planet needs 60% vegetation cover to keep planet within 5°-25°C temp range.
- Need for increased emphasis on monitoring/research to support understanding of CC impacts on BD.

Participant 16
- Threatening processes – needs more work/emphasis. Define all, start working with State agencies on the ones we can address – frequent fires, urban expansion/land use, fragmentation etc.
- Monitoring – it's not "sexy" but it is part of an essential baseline to define what is changing and how. Role of Commonwealth – great framework developed through NFI that could be expanded to all land systems – relevant to this and many other programs (NRM, SOER, NVIS/NFI etc).
- Loss of species – has the potential to consume many resources, time, public focus etc. Research, communication more info to public that the changes are part of a broader process/landscape.

Participant 17
- Is the reserve system adequate to maintain current BD even if CC was not an issue?
- Many major threats to reserves at the current time could be controlled/minimised by appropriate levels of funding and informed management. Should this be a priority?
- Is it appropriate to continue to develop ski resorts in the alpine reserves?
- The NRS is part of the habitats for many dispersive animal species. These use resources in space temporally. Large/more reserves may be required to secure their future regardless of CC (land use change may remove vital present habitat)



Participant 18
- Critical to emphasise that to maximise robustness/resilience of reserves and NRS network (+ species) that they need to be seen and managed as an inherent part of broader landscape. Need to institutionalise better regional/landscape planning approaches.

- Reality that social/cultural factors will play a significant part in determining management responses – what type and if any.
- Need to ensure descriptive science of climate and impacts is linked with on-ground land management.

Participant 19
- Marine issues influencing NRS – intertidal region, marine productivity (East Australia Current and ENSO).
- Visitor management and use – water resources, fire.
- Resources for managing the NRS, especially new acquisitions.
- Strategies to ensure viability of existing NRS (finer scale habitat corridors, managing agreements in adjacent lands, cooperative integrated pest control and national strategies.

Participant 20
- Connectivity conservation that includes the NRS needs to be developed at scale where systems & biomass extend across the continent and opportunities exist to identify and gain community support for their establishment.

Participant 21
- Need an integrated approach to conservation of BD across the whole landscape. This involves establishing a CAR NRS supported and buffered by connectivity conservation where possible across all tenures of land. This involves policies, planning, regulation and allocation of targeted in-perpetuity voluntary agreements on private land and other public land.
- This needs to be adequately supported by long-term stewardship incentive programs. These can where appropriate are market based mechanisms to most efficiently allocate resources.
- Land clearing (broad scale) must cease.

Participant 22
- I think the NRS process is still valid but agree that additional criteria for productivity should be incorporated.
- While recognising that the NRS process underpins conservation activities, we must begin to assess the impacts of CC on surrogates used for such a system. ie climatic envelopes for vegetation types. This will assist in delivering priority types for acquisition or off-reserve conservation.
- I think testing homogeneity across the climatic envelopes for individual taxa or assemblages will help in targeting what will and wont be conserved under changes climatic regimes.

Participant 23
- High productivity areas ~ phylogenetic, diversity, endemism, refuges, in landscape planning.
- Ability to respond to CC – available research, species data, taxonomic capacity. Ability to be able to identify, respond to and measure response to change in BD.
- Landscape permeability – influence on NRS and off-reserve planning.

Participant 24
- CC will make it even more important to ensure “sink landscapes” are protected for BD conservation.
- We should ensure that natural adaptation processes are facilitated not impeded by management.
- Connectivity (broadly defined) is needed to enable populations to be replenished or to disperse as situations dictate.

Participant 25
- Importance of identifying sensitive spp threatened by CC – identify other threats that can be managed now.
- Importance of identifying transformer species and looking at them.

- New threats: - possibly permanently decrease ground water in relation to critical part of (esp arid zone) ecosystems (mound springs, arid zone staging points).
- Need to identify cascading threats and components of habitats/ecosystems impacted.
- Don't discard translocations as an option – very successful in NZ and on some islands.
- Increase role of quarantine.
- Whilst connectivity will be important for ecosystems, there will be systems/spp that will do better if not connected. These need more thought. May be more relevant at microscale (insects etc).
- Internationally obliged to attempt to retain all spp – have signed CBD etc + most stat legislation reflects these obligations. Have to try!
- Other CC implications for reserve management need to be flagged eg impacts on water, tourism, heritage, infrastructure, sea level rise impacts.
- Need to identify management of new threats that may emerge and work out how to manage them collectively in relation to specific areas. Need research to understand these better.
- Look at applicability of risk management framework to developing management approaches.
- Importance of condition of potential areas to add to NRS.
- Management of the land is more important than status of the land – well managed private land can be more viable than poorly managed (lack of resources) park.
- Higher structural complexity of systems likely to be more resilient – likely to have greater redundancy.

Participant 26
- CC is a pervasive global threat that exacerbates all other threats, therefore focus should be on others that can be managed discretely within NRS context.
- NRS strategy has 3 key points.
  - Establish core NRS as per CAR (with addition of productivity)
  - Management of NRS as a static entity impacted by pervasive change
  - Integration of both these into broader landscape processes
- Managing/planning for CC is about managing/planning for change with climate as a key variable.

Participant 27
- How do we account for the fact that people "change" by small increments, approximation and rarely in leaps and bounds? What can be done versus what is likely to be carried out?
- Does the approach to using scenarios account for synergies among these?
- Can we distinguish between what is going to change anyway and anticipated changes due to climate?
- Is this like key spp indicators of ecosystem health - Adks report? Patterns of invasive spp or disease vectors

Attendees of the 1-day workshop on climate change impacts and the NRS

CSIRO Sustainable Ecosystems, Gungahlin, Canberra, Wednesday 7 February 2007.

Mike Dunlop	CSIRO Sustainable Ecosystems
Peter Brown	CSIRO Sustainable Ecosystems
Kristen Williams	CSIRO Sustainable Ecosystems
Michael Doherty	CSIRO Sustainable Ecosystems
Bruce Cummings	DEW
Tim Bond	DEW
Sarah Pizzey	DEW
Cameron Slatyer	DEW
Rachael Dempsey	DEW
Anna Van Dugteren	DEW – AGO
Liz Dovey	DEW – AGO
Jim Croft	DEW – ABG
Martin Fortescue	DEW Booderee
Brad Arkell	DPIW Tas
Mark Cowan	DEC WA
Alison Wright	DEH SA
Margaret Kitchin	Env ACT
Peter Young	EPA QLD
Rob Dick	NPWS NSW
Dan Faith	Aust Museum
Brendan Mackey	ANU
Sandra Berry	ANU
Virginia Young	TWS
Penny Figgis	WCPA/IUCN
Paul Sattler	Free agent
Nathan Males	Tas. Land Conservancy
Michael Looker	Nature Conservancy
Stuart Cowell	Bush Heritage
Ian Pulsford	NPWS NSW, Queanbeyan

Workshop Program

Impacts of climate change on the development and management of the National Reserve System

Workshop program
Wednesday 7 Feb, CSIRO Sustainable Ecosystems, Canberra

9:00 Welcome
- Housekeeping
- Goals for the project and workshop

9:15 AGO's involvement

9:20 Round table
- Introductions
- Update on climate change and biodiversity news/activities

10:00 Introductory presentations
- Framework for assessing impacts on the NRS
- Summary of impacts of climate change on biodiversity

10:30 Morning Tea

10:50 Warm-up discussion: Implications for conservation at various scales

11:20 Targeted discussions: possible adaptation responses to various impact scenarios
- When does it matter? (spp, time, space, flow on impact)
- What can be done about it? (Limited resources, Need to be effective and efficient)
- How would you know it is happening?
    - After it is too late, lag indicators!
    - Possible lead indicators; important processes?
    - Plan for the possibility it may happen, risk management

12:40 Lunch

1:30 Continue discussions of adaptation responses

3:45 Afternoon Tea

4:00 Closing discussion of "high level" issues
- What are we trying to conserve?
- How will priorities change?
- How to deal with nasty synergies and other interactions
- Can current planning tools cope?
- What are the impacts on the operation of C, A & R?
- Will it be more of an individual species or a "reserve system" issue?

5:00 Close formal proceedings