FAUNA CORRIDORS FOR CLIMATE CHANGE

Landscape Selection Process

Key Altitudinal, Latitudinal and Coastal Corridors for response to Climate Change

Hunter Central Rivers Catchment Management Authority (HCRCMA)

A report by
The Department of Environment and Climate Change.

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1 Introduction

This project was commissioned by the Conservation Partnerships, Parks and Wildlife Division to identify land areas for strategic investment of CMA funds to contribute to the conservation and effectiveness of large scale climate change corridors. The project has strong links to the recently announced “Alps to Atherton” (A to A) Climate Change Corridor and is essentially a finer scale interpretation of the A to A concept and function at a regional scale.

2 Scope

The assessment identified those areas of the landscape that represent large scale climate change corridors of optimum habitat for wildlife. The approach is essentially a rapid assessment of best available desktop data. The corridors are significant for the movement of wildlife that may be vulnerable to the adverse effects of climate change and other threatening processes.

3 Study Area

The Study area is the Hunter Central Rivers CMA region. Corridors have been delineated outside this study area for other clients and will be available as contextual information. Refer to Map 1 Appendix A.

4 Background

In the last few years an ever increasing volume of literature, reflecting the increasing research, on climate change has been produced. Despite this, projections regarding effects on biodiversity are of a much generalised nature. The range of predictions regarding the changes to weather patterns and the resulting effects on biodiversity are constantly being revised as new information becomes available.

The Commonwealth Scientific an Industrial Research Organisation (CSIRO) predicts that at current levels of greenhouse gas (GHG) emissions Australia will experience annual average temperature increases of 0.4-2.0 ° C by the year 2030 and 1-6 ° C by 2070. Average rainfall for the southeast Australia, in which the study area lies, is projected to decline along with increased erosion and inundation of the coastline as rainfall becomes more intense but less frequent. Higher average temperatures will cause higher evaporation and increase the incidence and intensity of bushfires (CSIRO, 2005).

As temperature and rainfall are major factors dictating the distribution of plants and animals it is expected that there will be direct and indirect effects on species and ecosystems across Australia.

The National Biodiversity and Climate Change Action Plan 2004-2007 (NRMMC, 2004) provides a national overview of the impact of climate change and provides strategies and actions to mitigate impacts of climate change on biodiversity based on knowledge complied in 2004.

It Identifies ecosystems and species which may be particularly vulnerable to the effects of climate change. These include species and ecosystems which are: - already considered vulnerable such as those in high altitude environments, restricted to small geographic areas, vulnerable to invasive species, dependent on flowering and fruiting, low-lying coastal areas, freshwater wetlands or vulnerable to increased drought and fire.

Wildlife species are capable of adaptation to a changing climate through migration, genetic adaptation and behavioural. Biodiversity has been subject to a changing climate historically. However, climate change is now a much more significant problem than in the past due to the pervasive threats to native species from modification of land and waters by human settlements, pastoralism, and other anthropological factors that result in the fragmentation of natural vegetation (WWF, IUCN,WCPA 2007).

The identification of broad landscape corridors for adaptation to climate change is beginning to gain some attention in the scientific and government areas. The recognition and announcement of the large ‘Alps to Atherton Corridor’ has established a greater interest and awareness for biodiversity management in relation to the emerging threatening processes from climatic change predictions.

It is now apparent that recognised threatening processes arising from habitat fragmentation such as habitat isolation, habitat degradation, edge effects, predator/prey ratios to name a few, are now compounded by the increased needs for adaptation of wildlife to the potential pressures and threats presented by climate change. The impact of climate change scenarios on biodiversity have been briefly investigated in this report. These investigations of the current ideas and principles surrounding climate change have been integrated to establish a set of working principles and criteria which formed the basis for the design and development of the project outputs.

This approach works from within a theoretical framework that landscape connectivity will play a major role in both the adaptation to climate change effects and the continuation of wildlife ecological processes in a changing climate. This hopefully will be achieved by increasing gene flow between different populations of species to maximise their chances of exploiting changed conditions. This approach is consistent with actions identified for “the protection of habitat for terrestrial and marine species or ecosystems vulnerable to climate change” (NRMMC, 2004) and the key elements for enhancing resilience listed below.

In a the recent symposium on protected areas and climate change (sponsored by the Australian Greenhouse Office and the Department of the Environment and Water Resources), the issues of climate change resilience and the role of the National Reserve System were presented. Key directions for enhancing natural resilience were reported as

- Identify and protect climate refugia
- Conserve large-scale migration corridors
- Maintain viable populations to enable adaptation
- Reduce threatening processes at the landscape scale
- Conserve natural processes and connectivity at the landscape scale and
- Special interventions to avert extinctions

(Taylor, M and Figgis, P 2007 in “*Protected Areas: buffering nature against climate change – overview and recommendations*” page 2”)

This project seeks to use best existing desktop data to delineate large-scale migration corridors that can be used as a basis for addressing the above-mentioned actions and conservation priorities for climate change.

5 Rationale and Principles of Design

From the discussions above the following principles have been used for the basis of the design and delineation of broad wildlife corridors for adaptation to climate change pressures.

The overall rationale is to provide connectivity of similar habitats along climatic gradients and links between threatened landscapes to refugia.

The following principles of design were integrated into the analysis and decision making for corridor delineation.

- Identification of large scale migration corridors across climatic gradients.
- Reduction in edge effects on reserves and existing vegetation.
- Linking threatened landscapes
- Linking formal protected areas
- Linking key habitats
- Incorporating habitat mosaics
- Buffering and/or expansion of protected areas and linking refugia.

6 Methods

6.1 Interpretation of additional products from the Key Habitats and Corridors for forest fauna of north-east NSW (Scotts, 2003)

The “Key Habitats and Corridors for forest fauna” published by Scotts (2003) was considered the most suitable model and data on which to base the assessment. This work and the associated data products provided a sound basis on which to establish preliminary design and development. It is the only broad-scale network of wildlife corridors and habitats which covers the whole of the study area. The methodology has been widely reviewed and accepted.

The objectives of this project were to broadly delineate large-scale corridors based on existing mapped corridors from previous work and their significance for adaptation to climate change. To develop this approach, corridor maps for specific fauna assemblages were examined and grouped according to broad habitat requirements based on supplementary data from Scotts (2003). This allowed for climatic gradients and habitat mosaics to be incorporated into the design. The final ‘broad’ assemblages were constructed from the grouping of Scotts (2003) assemblages as shown in Table 1. This process identified three broad habitat assemblages which formed the basis of the climate change corridors delineation. These were moist habitat, dry habitat and coastal habitat assemblages. Table 1 illustrates the groups (assemblages) and their amalgamations.

Climate Corridor Assemblages	Key Habitats and Corridors – Assemblages - Scotts, (2003)
1. Moist Habitat Fauna Assemblages	(LNE) Wet Eastern Tablelands
	(LNE) Mid North Coast Wet Escarpment
	(LNE) High Elevation
	(LNE) Moist Escarpment Foothills
	(TAB) Wet Eastern Tablelands
	(TAB) Wet Escarpment Eastern Tablelands
	(SYD) Wet Coastal Ranges
2. Dry Habitat Fauna Assemblages	(LNE) Dry Valley
	(LNE) Dry Eastern Tablelands
	(LNE) Dry Coastal Foothills
	(TAB) Dry Eastern Tablelands
	(TAB) Southern New England Tablelands
	(TAB)Dry Western Tablelands
	(SYD) Dry Valleys
	(TAB) Dry Granite Tablelands
	(SYD) Dry Western - Central
	(SYD) Dry Sandstone
3. Coastal Habitat Fauna Assemblages	(LNE) Coastal Complex
	(UNE) Dry Coastal Foothills
	(SYD) Coastal complex
	(SYD) Dry Coastal Ranges
	(LNE) Dry Coastal Foothills

Table 1 Grouping of Scotts (2003) fauna assemblages into broad Habitat Assemblages for Climate Corridors in the Hunter Central Rivers CMA

6.2 Initial delineation of Climate Change Corridors for dry, moist and coastal Assemblage fauna species

Climate Change corridors for three broad habitat assemblages were initially delineated by using a visual assessment of the landscape based on the spatial mapping of specific fauna assemblage corridors as derived by Scotts, D. and Drielsma, M.J. (2003).

The coastal delineation was based on the original mapping for the coastal complex fauna assemblage as derived by Scotts, D. and Drielsma, M.J. (2003). Extant vegetation was linked. Cleared areas and agricultural land that fit into a context of a climate change corridor was also included.

6.3 Refinement of Corridor framework

The initial corridors framework was reviewed and analysed to determine refined boundaries using more recent habitat quality models, vegetation mapping and visual checking using SPOT5 satellite imagery. The coastal corridor refinement included the additions of coastal wetlands and water-bodies.

An expert workshop was carried out on the “first cut” of areas from the process. This process used expert knowledge to refine the delineations. There was also further evaluation of the “input” map layers which formed the basis of design for proposed corridors such as:

- Mapped Fauna Assemblage Corridors specific to Moist, Dry or Coastal Assemblages (Scotts, D. and Drielsma, M.J. 2003)
- Fauna assemblage habitat models (Scotts, D. and Drielsma, M.J. 2003)
- Analysis of vegetation patterns from the Forest Ecosystems remodelling (CRA – unpublished)
- Recent fauna and flora records from NSW Wildlife Atlas throughout and adjoining the study area.
- Recent broad outputs from the Spatial Links tool (Dreilsma, M, Manion, G and Ferrier, S. 2007)

6.4 Reference species designation

The expert review process identified reference species that were specifically associated with each corridor. These species were identified as vulnerable to climate change using a process of expert evaluation on the relative vulnerability to the adverse effects of climate change (see discussion below). In some cases two reference species were selected as climate change icons for a particular corridor. The species nominated for each corridor were species of particular conservation significance that related to each corridor location, habitat and arrangement and are intended for community recognition and awareness rather than a robust scientific indicator species.

During peer review workshops, selection and attribution of reference species for each corridor was conducted. Reference species were selected based on review of the following information;
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- Atlas fauna records
- Habitat mapping and modelling where available
- Known hotspot localities
- Expert knowledge of populations
- Vegetation mapping

The reference species serves as an icon to support community identification, awareness and understanding.

Species nominated as reference species may not be so vulnerable in other parts of their range; however the population has been assessed to have some vulnerability to threatening processes presented by climatic change predictions. It is not intended that conservation efforts should be structured solely for the benefit of the nominated reference species at the expense of other conservation values. A whole of ecosystem approach should be undertaken with consideration of the reference species as an identifier.

6.4.1 Climate Change reference species– evaluation of “species at risk”

Fauna species with the assemblage groups developed by Scotts, D. and Drielsma, M.J. (2003) were examined to evaluate those species most at risk to climate change pressures. Those selected were then ‘short listed’ for the selection of “reference” species to associate with particular climate change corridors. Criteria on which to base this evaluation included the following factors;

- Species which depend on landscapes predicted to be particularly vulnerable to climate change process, for example rainforest.
- restricted distribution,
- limited dispersal ability,
- specialised habitat requirements,
- small populations and/or low genetic diversity. In particular species endemic to high mountain environments, freshwater wetlands and islands are highly vulnerable. (NRMMC, 2004).

Other climate change pressures considered to impact on species at risk include;

- Vulnerability to opportunistic pest species which are adapted to take advantage of a range of climatic conditions, such as the red fox.
- Increase in virulence of viruses and parasites due to higher temperatures.
- Changes in structure and composition of vegetation communities as a result of changes in rainfall and temperature regimes will affect species adapted to existing regimes. This will directly affect nectarivores, frugivores and species dependent on hollows and fissures in old growth forests for habitat.
- Rising seal levels will mean species dependent on mangroves, coastal wetlands and seagrass will be directly affected.
- It is also expected that bushfires will increase in their frequency, intensity and extent. This will particularly affect species adapted to wetlands and rainforest as many existing moist habitats become drier (NRMMC, 2004).

6.5 Corridor names

Corridors were identified and labelled based on location, landscape features or protected areas in close proximity. This was established to facilitate community identification and “ownership’ with the mapped corridors.

6.6 High Conservation Value Linkages

The Corridors networks were analysed and tagged as HCV linkages if a significant area of its extent contained key habitat. Key Habitats mapping from Scotts, D. and Drielsma, M.J. (2003) was utilised to calculate the areas. This outcome provides a quick reference for corridors which already support significant populations of species vulnerable to climate change. The selection of these HCV linkages was based on at least 30% mapped coverage of key habitats within the corridor.

6.7 Spatial Configuration Features

The following features were delineated within the corridors. Each corridor was split into sections based on these spatial configuration features. The sections were delineated based on the spatial configuration of the vegetation according to a visual analysis using Spot 5 satellite imagery (2005) and a consideration of the various conservation actions required over those features. The features are labelled to reflect the spatial configuration and the conservation action priorities and area summarised in Table 2 below.

Feature Label	Spatial feature	Conservation Action
Stepping Stone consolidation or development	Fragmented vegetation and remnants acting as viable corridor for selection of species.	Protection of existing vegetation and strategic re-establishment of vegetation to enhance 'stepping stone" pattern.
Valley Floor Linkages	Usually highly cleared or highly threatened fertile areas along alluvial flats.	Re-establishment of vegetation either as windbreaks or patches – in a stepping stone strategy.
Protect and Enhance	Usually extensively vegetated areas within the corridor.	Protection and rehabilitation of existing vegetation
Reserve Buffers	Predominantly extensively vegetated areas within the corridor and high proportion of mapped key habitats for wildlife.	Protection of vegetation (under covenant) to ensure buffers and expansion to formal reserve system
Reserve Buffers and Linkages	Predominantly extensively vegetated areas within the corridor and high proportion of mapped key habitats for wildlife.	As above with a view to creating strategic "linkages" of protected areas between formal reserves.
Floodplain Linkages	Sites of high fertility and productivity which were most comprehensively cleared for agriculture. The cleared floodplains of the study area represent major barriers to dispersal for many species.	Expansion of riparian vegetation, and connection to key habitats via stepping stones, creeks and ridgelines.
Linkage onto Tablelands	Extensively cleared high altitude landscapes which are predicted to become drier. East and west linkages vital to enable gene flow between refugia.	Linking remnant vegetation along rivers and in TSRs.
Coastal connectors	Areas which are a mosaic of reserves, public lands forming stepping stone linkages of semi cleared ridges, small wetlands, and riparian strips	These will require a combination of the strategies outlined for other features
Major Wetland Areas	Function as refugia during periods of drought. May be in heavily cleared floodplain or tablelands or in forested areas.	Encourage habitat protection in and around wetland areas through bush regeneration and reduce threatening processes such as fire, water extraction, grazing and feral predators.

Table 2: Summary of Corridor Features and descriptions

7 Results and Discussion

7.1 Moist Fauna Assemblage Group

The analysis identified 11 major corridors in the study area for the moist forest fauna assemblage which are summarised in table 3 below. The corridors link major moist habitats such as high altitudinal rainforest and wet sclerophyll and moist eastern foothills forests of northern NSW. The moist habitat assemblage corridors network links contiguous areas of forest across altitudinal gradients and latitudinal gradients. (Refer Map in Appendix B) Reference species are predominantly rainforest and high altitudinal species considered quite vulnerable to the impacts of climate change. There is an absence of moist corridor connection across the Hunter Valley due to the drier environments occurring there and the fact that the Hunter Valley is a natural dry barrier for many moist habitat species. This area is predicted to become drier rather than wet under climate change.

The corridors designated HCV Linkages highlight the areas where populations of moist assemblage species will be present in the corridor based on the presence of areas of key habitat.

Corridor Name	**CC Reference Species 1**	**CC Reference Species2**	**HCV**
Barrington to Muswellbrook	Sooty Owl		
Barrington to Myall	Grey-headed Flying Fox	Sooty Owl	
Barrington to the Hunter River west	Koala		
Bulga Giro Connector	Parma Wallaby	Wompoo Fruit-dove	
Great Lakes - Barrington	Stuttering Frog	Sooty Owl	HCV
Mid North Coast Escarpment - Barrington	Giant Barred Frog	Sooty Owl	HCV
Patterson to West Barrington	Koala	Grey-headed Flying Fox	
Saltwater - Upper Manning	Yellow-bellied Glider	Sooty Owl	
West Hunter River Loop	Sooty Owl		HCV
Wet Coastal Ranges - Escarpment	Yellow-bellied Glider	Sooty Owl	HCV
Wollemi	Yellow-bellied Glider		

Table 3: List of Dry assemblage fauna climate change corridors and assigned reference species. (Please note: Figures for NRCMA area only at this stage)

Corridor Feature	**AREA HA**	**% vegetated**	**% key habitats**	**% Old growth**	**% Rainforest**
Protect and Enhance Existing Hab	129189	92	15	3	1
Reserve Buffers	68220	78	25	2	2
Reserve Buffers and Linkages	697362	91	42	17	15
Stepping Stone Consolidation	82749	59	7	9	12
Stepping Stone Development	27689	38	1	4	1
Valley Floor Linkages	45600	19	3	0	1

Table 4 Relative proportions of vegetation and HCV values within corridor features for moist assemblage fauna species.

The summary above demonstrates briefly some of the values held within each corridor feature. The corridor features have common elements according to their habitat values, the spatial configuration of vegetation and other conservation values.

7.2 Dry Fauna Assemblage Group

25 corridors were identified in the Hunter Central Rivers CMA for the dry habitat assemblage network and are briefly summarised below in table 5 below. There was a strong network of corridors and associated key habitats for dry habitat assemblages across the Hunter Valley in locations where moist habitat assemblages were absent. The Hunter Valley has historically represented a 'dry' barrier to many moist habitat fauna species and will continue to be so under climate change predictions.

HCV Linkages highlight the areas where good populations of dry assemblage species should be already utilising the corridor based on the presence of areas of key habitat.

Corridor Name	Reference Species 1	Reference Species 2	HCV
Barrington Tops	Broad-toothed Rat		HCV
Barrington Tops-Patterson	Squirrel Glider	Grey-headed Flying-fox	
Barrington-Muswellbrook	Woodland Birds	Koala	
Belford-Werakata	Woodland Birds	Squirrel Glider	
Copleland Tops-Goulburn River	Woodland Birds		
Curracabundi-Barrington Tops	Wombat	Davies Tree Frog	
Glenrock-Scone	Woodland Birds	Booroolong Frog	
Goulburn River-Wollemi	Woodland Birds		
Great Eastern Tableands Corridor	Woodland Birds	Brush-tailed Rock Wallaby	
Jilliby-Brisbane Water	Red-crowned Toadlet		HCV
Jilliby-Yengo	Koala	Giant Burrowing Frog	HCV
Karuah-Port Stephens	Coastal Emu	Koala	HCV
Liverpool Range	Greater Glider	Wombat	
Liverpool Range-Manobalai	Woodland Birds	Wombat	HCV
Mummel Gulf - Nowendoc	Wombat	Davies Tree Frog	HCV
Munghorn Gap-Wollemi	Woodland Birds		
Muswellbrook-Wollemi	Woodland Birds		
Pokolbin	Woodland Birds	Brush-tailed Rock Wallaby	HCV
Pokolbin-Karuah	Woodland Birds	Brush-tailed Phascogale	
Ravensworth-Wollemi	Green and Golden Bell Frog	Squirrel Glider	
Ulan-Munghorn Gap	Woodland Birds	Squirrel Glider	
Werakata	Woodland Birds	Swift Parrot	HCV
Wollemi	Woodland Birds	Brush-tailed Rock Wallaby	
Woolooma-Barrington	Woodland Birds	Koala	
Yengo-Brisbane Water	Red-crowned Toadlet		HCV

Table 5: List of Dry assemblage fauna climate change corridors and assigned reference species. (Please note: Figures for NRCMA area only at this stage)

Corridor Feature	Total Area	%vegetated	% Key Habitat	% Old Growth
Linkage across Floodplain	67745.3100	20	14	3
Protect and Enhance Existing	44272.5800	96	53	8
Reserve Buffer	45837.7600	94	72	20
Reserve Buffers and Linkages	1043660.0700	58	19	4
Stepping Stone Development	54247.0000	11	3	2
Stepping Stone Remnants	75217.5300	26	2	2
Valley Floor Linkages	465550.6200	57	15	5

Table 6: Relative proportions of vegetation and HCV values within corridor features for dry assemblage fauna species. (Please note: Figures for NRCMA area only at this stage)

The data above demonstrates the relative extant vegetation coverage in corridor features. For example, “linkage across floodplain” features are far less vegetated than “reserve buffer” features. This indicates that conservation actions in these areas would predominantly be based on rehabilitation and re-establishment of vegetation.

7.3 Coastal Complex Fauna Assemblage Group

The Hunter CMA coastal area was divided into six major coastal corridors. Of these, three were considered to be High Conservation Value. A key faunal species for the Hunter Coast is the Koala. There are important populations in the coastal forests throughout this area, however much of the habitat is fragmented. Reconnection and restoration of these forests should be a priority for future works. Key faunal species such as Brush-tailed Phascogale and Squirrel Gliders will also benefit from the enhancement of coastal forests on the Hunter coast.

Coastal wetlands are also a major habitat of importance on the Hunter coast. Many species of frogs are restricted to coastal environments and the wetlands of the Hunter coast are important areas which, over the long term, can provide stronghold populations for coastal fauna. Projects which restore natural drainage and allow for the wetland systems to exist without pressure from agriculture and urban development will enhance the viability of wetlands of the Hunter Coast.

Corridor Name	Reference Species 1	Reference Species 2	HCV
Crowdy Bay – Lower Manning	Black-necked Stork	Wallum Froglet	
Karuah – Hunter	Koala	Green and Golden Bell Frog	HCV
Lake Macquarie - Gosford	Koala	Wallum Froglet	HCV
Lower Manning - Wallingat	Koala	Brush-tailed Phascogale	
Newcastle	Squirrel Glider	Grey-headed Flying Fox	
Wallingat - Karuah	Koala	Green and Golden Bell Frog	HCV

Table 7: List of coastal assemblage fauna climate change corridors and assigned reference species. (Please note: Figures for NRCMA area only at this stage)

Table 8 shows that while there are relatively large areas of extant vegetation in the Hunter coastal corridors, the percentage of Key Habitat and Old Growth is relatively low overall. The area of Key Habitat is a subset, in many cases a small subset, of the existing vegetation. Likewise, the area of old growth is a very small percentage of extant vegetation, in many cases less than 5% of the area. Priorities for particular corridor features should focus on improving the marginal areas, for example joining of stepping stone remnants and enhancing existing lower-quality vegetation stands. The protection of existing HCV vegetation can include improving reserve buffers, and providing links from the coast to the hinterland as well as between coastal habitats. Wetlands are a major feature of the Hunter coast landscape and include a significant proportion of Key Habitat areas.

Corridor Feature	Area	% Extant Veg	% Key Habitats	% Old growth
Linkage across floodplain	149802	60	25	4
Major wetland area	9924	72	36	9
Protect and enhance	22347	68	28	
Reserve buffer	163930	83	50	10
Stepping stone remnants	3626	35	2	0
Valley floor linkage	98069	52	20	1

Table 8: Relative proportions of vegetation and HCV values within corridor features for coastal assemblage fauna species. (Please note: Figures for NRCMA area only at this stage)

8 SUMMARY OF OUTPUTS AND PRODUCTS

8.1 Separate digital spatial data layers for each fauna assemblage including moist, dry and coastal assemblages. Data structured in an Arcview GIS format.

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The layer delineates a key climatic gradient corridors network to provide for moist, dry and coastal faunal assemblage groups to respond to climate change pressures.

8.2 Corridor Names and Reference Species

Names are attributed to each delineated corridor based on the location in the landscape. Reference species associated with each corridor in regard to climate change values and vulnerability.

8.3 Corridor Features for Moist and Dry Fauna Assemblage networks

A visual analysis of the SPOT5 satellite imagery and vegetation mapping data revealed various features within the corridors that will assist in strategic planning for conservation actions. These are described below.

8.3.1 Protect and Enhance

The characteristics of this corridor feature are predominantly high levels of vegetated land, presence of high conservation value forest and a level of continuity with adjacent areas of vegetation or reserves or other public land. The priorities in these areas would generally be focused on the protection of the existing high conservation value features, or some enhancement of existing vegetation through plantings, weed management and removal threatening processes.

8.3.2 Reserve Buffers and Linkages

These corridor features are predominantly delineated around or linking existing formal reserves and some other public lands. The areas are predominantly vegetated and contain large areas of key habitats and other high conservation value features such as old growth forest, wetlands, rainforest and forest that have been subject to less disturbance and fragmentation.

8.3.3 Stepping Stone Consolidation

These areas are classically fragmented and contain remnant vegetation that may be subject to edge effects. The areas are somewhat compromised in terms of viability for acting as wildlife corridors for species which will not disperse large distances over open areas but can be utilised by other species , especially bats and birds. In some instances they are more effective than narrow linear corridors which are dominated by edge loving species and thus represent important priority areas that require consolidation, maintenance and protection. The priorities in these areas would include;

- strategic re-establishment of vegetation,
- rehabilitation - weed management, feral animal removal
- protection of existing remnants
- nest boxes.
- Stepping Stone areas enhance landscape connectivity and will provide good connectivity for a subset of more mobile species such as bats, birds and insects.

8.3.4 Floodplain Linkages

The cleared floodplains of the study area represent major barriers to dispersal for many species. It is recognised that considerable resources would be required to complete these links however their importance should not be ignored. The higher productivity, access and permanent water of the major river systems will make these areas a high priority for conservation activities to address climate change. These have been refugia in past droughts and should be a high priority for future conservation efforts. Projected increased salinity in these areas may mean land becomes available for conservation as farming becomes unviable.

8.3.5 Linkage onto Tablelands

These areas are delineated as the most effective in improving connectivity for this highly threatened high altitude landscape. The extensive clearing and fragmentation of this area along with the projected higher temperatures and evaporation mean that many species and ecosystems already at risk further west may only survive along the tablelands/escarpment ecotone. Improving the connectivity along this predominately east to west gradient should be seen as a high priority.

8.3.6 Valley Floor Linkages

These are typically areas that link vegetation across the more productive, and thus heavily cleared alluvial flats and riparian areas. These areas are usually more fragmented and in poorer condition, however contain a high level of importance in terms of, productivity, connectivity and wildlife movement. Conservation actions would predominantly be associated with re- vegetation in strategic “stepping stone” locations and configurations.

8.4 Corridor Features for Coastal Complex fauna assemblage networks

The coastal corridor has been developed using different methodology in delineating features. The geomorphology found within the long narrow coastal strip does not easily ready itself to splitting into discrete features similar to the dry and moist corridors. It also has its own unique set of climate change pressures and existing threatening processes. Sea level rises are expected to have a devastating effect on low level estuarine and freshwater wetland environments. Corridor features were categorised as a "Linkage across Floodplains" (as described above), "Major Wetland areas" or Coastal connector".

8.4.1 Major Wetland Areas

These areas which may be inundated with salt water and change the make of wetland communities dramatically. Cleared areas immediately adjacent to areas currently supporting wetland ecosystems should be targeted as they will be increasingly important as sea level rises.

8.4.2 Coastal Connectors

Areas which are a mosaic of reserves, public lands forming stepping stone linkages of semi cleared ridges, small wetlands, and riparian strips. These will require a combination of the strategies outlined for other features

8.5 Quantitative statistical information on conservation values:

Statistical information regarding each corridor section is built into the attribute table and can be analysed to evaluate conservation actions and funding requirements. The following information is included:

- Vegetation area (All fauna groups)
- Old growth area (All fauna groups)
- Key habitat area (All fauna groups)
- Coastal Wetland area (Coastal group)
- Rainforest area (Moist and Coastal group)

The area of these conservation features, in hectares and as a percentage of corridor area. This information is built into the attribute layers of the GIS spatial database.

9 Limitations to the project outcomes

9.1 Isolated vulnerable Habitats

It may not be possible to connect some vulnerable habitats, such as isolated wetlands due to geographic or geological conditions or islands by vegetative corridors. In these instances localised threatening process should be minimised and other conservation strategies explored.

9.2 Floodplain remnants and linkages

In some areas opportunities to establish Floodplain Stepping Stones may arise which are outside delineated corridors. If this occurs in heavily cleared areas it would be prudent to revegetate these areas if no other property is available in the area.

9.3 Riparian corridors

Riparian areas are natural corridors for many species and should be considered a priority to maintain and enhance. Riparian Corridors were not specifically delineated by Scotts (2003) as they are already clearly defined in the landscape.

Although riparian corridors are not extensively mapped in the project outputs, it is essential that these areas receive protection, re-habilitation and even expansion to help complement an overall landscape connectivity approach to climate change. Lindenmayer and Fisher, 2006 state that ‘Riparian corridors or stream buffers are a particular type of corridor that can often be particularly effective at maintaining habitat connectivity (Kirchner et al. 2003; Hilty and Merenlender 2004). They provide habitat for large numbers of terrestrial and aquatic fauna and flora (Loyn et al. 1980: Naiman et al. 1993; Spackman and Hughes 1995). In addition, populations of several groups of species are more fecund in riparian areas (Sederquist and Mac Nally 2000), thereby providing more offspring to disperse to the less productive parts of the landscape.’

In terms of connectivity, however, Lindenmayer and Fisher, 2006 go on to state that’ while riparian areas are useful for some terrestrial taxa, physical linkages outside the riparian zone are required to maintain landscape connectivity for other taxa (McGarigal and McComb 1992; Claridge and Lindenmayer 1994).

In terms of our recommendations for further corridor and landscape connectivity work, riparian corridors should feature strongly in any mapping of floodplain ‘stepping stones’ as an essential supplement to the existing broad corridors networks presented by this project.

10 Caveats

Lindenmayer and Fischer 2006 discuss some of the apparent disadvantages with wildlife corridors which should be considered. The discussion states that ‘corridors may facilitate the spread of genes that break up co adapted gene complexes in naturally isolated population (Knopf, 1992). They may also exacerbate the spread of weeks, pest animals, diseases, and fires (Forney and Gilpin 1989). Corridors may be dominated by negative edge effects (Sisk and Margules 1993).

These disadvantages should be considered in the allocation of resources for conservation actions. Any re-establishment or rehabilitation of vegetation should also include strategic follow up actions and resources to reduce the impacts of weeds and edge effects and allow for the area to grow spatially and structurally.

The design of this project is based on climate change projections at the lower end of the predicted changes. This is dependent on a steady reduction in carbon emissions occurring within the next 10-15 years and annual temperatures across the study area not rising by more than 2 degrees C. If emissions are not drastically reduced and temperatures rise by 3-6 degrees C then the measures outlined in this report will be ineffectual.

11 Recommendations for Further work

- This project provides for the basis broad scale network of vegetated corridors, along climatic gradients linking with the Alps to Atherton continental scale corridor, to assist threatened wildlife populations adjust as projected ecological changes due to climate change occur.

- Further work to delineate stepping stone corridors across and between the most threatened landscapes such as floodplains, wetlands, lowland forest areas and low lying coastal landscapes needs to be established as a major incentive to mitigate the increasing pressures of habitat fragmentation on fauna assemblages that rely on these landscapes and their habitat for survival.

- Further refinement is needed to define the corridor network at a local rather than regional scale to increase the effectiveness of the mapping for planning on ground conservation works at a property scale.

- Further research is needed to better understand the effects of climate change on biodiversity in the study region.

- Systematic fauna surveys are needed to determine the value of corridor linkages to different faunal assemblages.

- Research is needed on the population dynamics of vulnerable species in the study area to help improve strategies to maximise gene flow in a way which is of benefit to the species or population. This will assist in determining the effectiveness of different patch sizes for different species,

- Good baseline ecological data, such as current range and distribution, is lacking for the study area, particularly in the west. Collecting this data should be a priority so that changes caused by climate change can be recognised. Migratory species are particularly important as changes in their arrival and departure times may signal the onset of dramatic changes.

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APPENDIX A

MAP 1: Map of the Study Area for Climate change Corridors project - HCRCMA

APPENDIX B

Map 2: map of Climate Change Corridors for the Hunter Central Rivers CMA region